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In This Issue

There need be no conflict between theory and statistical analysis in the field of demand and prices. They are both essential. And they need to march hand in hand. Frederich V. Waugh, ***Demand and Price Analysis,*** *1964*

The seal of true science is the confirmation of its forecasts; its value is measured by the control it enables us to exercise over ourselves and our environment. Henry L. Moore

In a recent issue of this journal, Jet Yee found substantial returns to both public and private investment in agricultural research. But not all research activities yield positive returns and some are better suited to public rather than private investment. Consequently, there is often a need to prioritize prospective research projects which compete for federal research funds. Beach and Fernandez-Cornejo examine the issue of prioritizing projects competing for government support by the Alternative Agriculture Research and Commercialization (AARC) Center. The 1990 Farm Bill provided for the establishment of the AARC Center to develop and produce marketable products other than food, feed, or traditional forest or fiber products, and to direct research and commercialization efforts towards commodities that can be raised by family-sized agricultural producers. The AARC Center can provide financial incentives in the form of loans, interest subsidies, venture capital and repayable grants that are matched by private and local funds. This paper develops a pragmatic, three-phased, scoring model to evaluate and prioritize AARC Center proposals.

Economists often employ econometric models to quantify impacts of actual or proposed programs. How well this can be done is often a bone of contention. Those conducting and reporting the analyses seldom emphasize the limitations or degree of uncertainty surrounding their estimates. When they do, it tends to focus on statistical confidence intervals derived from their models. Unfortunately, these confidence intervals assume that the models accurately represent the real world including all the underlying assumptions. Of course, the assumptions are not always in close proximity with reality. For example, classical regression analysis requires that the explanatory variables be measured without error. If random error is present in the data, then the regression estimator is biased. Uri investigates the potential of inaccuracy in the price data for substitute sweeteners on the estimation of the demand for sugar. Two diagnostics are introduced to assess the impact of measurement error on the estimated coefficients. Uri suggests that measurement error in the price of sweetener substitutes has led to over-estimation of the response of sugar quantity demanded to changes in soft drink sales and personal disposable income. He finds this bias for both beverage sugar and nonbeverage sugar demand.

Another assumption commonly employed in economic models of production is that the production function is homogeneous. Price investigates the theoretical implications of this assumption for elasticities of input demand. He first notes, as many others have, that the degree of homogeneity must be less than one for a unique, profit-maximizing solution for a firm. He finds that the homogeneity assumption restricts the range of input demand elasticities to the elastic region when the degree of homogeneity is less than one. Furthermore, the input demand elasticity will be constant and equal for all inputs used in production. Consequently, the homogeneity assumption may not be appropriate for some empirical analyses.

Henry Kinnucan and Desmond O'Rourke write glowing, provocative reviews of two edited volumes. O'Rourke reviews a recent volume edited by Lopez and Polopolus entitled "Vegetable Markets in the Western Hemisphere." The book, reports O'Rourke, is an outcome of a conference held in 1988 at Rutgers University, and is an excellent exploration of the major influences shaping vegetable markets in the Western Hemisphere and, perhaps, around the world. O'Rourke is quite complimentary to the conference organizers for their insight into choosing speakers as well as to the speakers themselves. His only criticism is the fact the conference occurred in 1988 and was unable to consider major developments such as GATT and NAFTA.

Kinnucan reviews the book "Demand Analysis, Econometrics, and Policy Models: Selected Writings by Karl A. Fox." Kinnucan thinks the volume, edited by Johnson, Sengupta, and Thorbecke, will provide many hours of engaging reading to people who like to study a subject area through the greats

of the profession. He adds that the collection of writings will be especially helpful to students of agricultural price analysis because it focuses on issues of enduring interest, such as model specification, simultaneity, and measurement error, with the “grace and clarity that is at once refreshing and enlightening.” A strong recommendation indeed.

James Blaylock
David Smallwood

Setting Research Priorities in the Public Sector: A Suggested Framework for the AARC Center

E. Douglas Beach and Jorge Fernandez-Cornejo

Abstract. *An argument can be made for public support of pre-commercial research and development (R&D) when private industry, acting in response to market incentives, underinvests in socially desirable projects. Research projects meeting this criterion must still compete for scarce public funds. The Alternative Agriculture Research and Commercialization (AARC) Center was mandated by Congress to support pre-commercial R&D in new uses of agricultural commodities. This article develops a three-phase scoring model to evaluate and prioritize AARC Center proposals.*

Keywords. *pre-commercial R&D, market failure, AARC Center.*

As budgets tighten in all levels of government, public agricultural research systems are being asked to do more with less. The study of economics involves the assessment of alternative investments given scarce funds, so economists are well-suited to assist researchers with priority-setting methods and processes. As Stuby (1991) observes, priority setting in general "is a legitimate part of positivistic, rationalistic science and management." He adds, however, that not all priority setting is rational or positivistic. Generic, systemic problems must be resolved, including the difficulty of reducing complex issues to their elemental properties and of ordering multidimensional projects. Multidimensionality is of particular concern in agricultural research given the unidimensional character of most priority-setting procedures. This article examines these issues with respect to the newly established Alternative Agricultural Research and Commercialization (AARC) Center.

The 1990 Farm Bill (title XVI, subtitle G) provides government support for "pre-commercial" development of nonfood and nonfeed uses of agricultural commodities. The stated purpose of subtitle G is to help develop and produce marketable products other than food, feed, or traditional forest or fiber products; commercialize new nonfood, nonfeed uses of agricultural commodities; and direct research and commercialization efforts toward agricultural commodities that can be raised by family-sized agricultural producers (See appendix). Fulfillment of subtitle G is to be directed by the AARC Center.

The Center may provide financial assistance in the form of loans, interest subsidy payments, venture capital, and repayable grants. The AARC Center may also establish peer review committees with agricultural, scientific, technical, or other expertise, whose duties shall be to provide analysis and recommendations, on scientific, technological, and policy matters. Thus, the legislation explicitly encourages the Center to review all prospective programs and projects. Peer review is a necessary first step in preventing the AARC Center from adding to the widely publicized government "pork barrels" of the past (Cohen and Noll, 1991).

This article develops a three-phase scoring framework to help guide the peer review process for the AARC Center. The first phase involves an initial screening of applications to ensure compliance with the basic program. The principal investigators of those applications that meet the basic requirements are contacted for a more complete proposal in phase 2. Those proposals that are "recommended highly" or "recommended with comments" in phase 2 would be evaluated in phase 3. The highest ranked proposals in phase 3 are designated as semi-finalists and their ranking submitted to the Board. Funding decisions would then be made by the Board.

The evaluation criteria developed here borrows from methods used by various USDA organizations (Agricultural Research Service, Cooperative State Research Service, Cooperative State Research Service/Small Business Innovation Research Program, Economic Research Service, and Office of Energy); other Federal Government departments (Department of Commerce/Advanced Technology Program, Department of Commerce/Engineering Research Centers, and Department of Energy); State organizations (the Ben Franklin Partnerships in Pennsylvania and the North Carolina Experiment Station); and private industry (Archer Daniels Midland and Farmland Industries).

Beach and Fernandez-Cornejo are agricultural economists with the Resources and Technology Division, ERS. The authors express their gratitude for helpful comments from J. Alston, G. Gajewski, L. Glaser, M. Ollinger, N. Uri, and two anonymous reviewers.

An Economic Rationale for Government Support of Research and Development

The United States is a strong net exporter of technology, leading the world in the number of patents, licenses, fees, and other transactions. As of 1989, the United States had a net surplus of $1.3 billion in its technological balance of payments (National Academy of Sciences, 1992).[1]

Yet, when it comes to manufacturing technologies, data suggest that U.S. firms may lag behind some foreign competitors in the rate of adoption and the intensity of utilization of new technologies. Daniel F. Burton, the executive vice president of the Council on Competitiveness, believes U.S. industrial policy often favors research and development over demonstration and adoption. More specifically, Burton argues that U.S. industrial policy treats technology transfer as an incidental dividend of government research and development (R&D)[2], and not as the primary objective. In contrast, German and Japanese policies are designed to promote the application and diffusion of new technology (National Academy of Sciences, 1992).

Public support of pre-commercial R&D in Japan and the European Community (EC) may be higher than in the United States. For example, through efforts like the MITI and Key Technologies programs, Japan has promoted partnerships among business, universities, and government "downstream" from basic research. Manufacturing extension services, capital subsidies, accelerated depreciation, and direct subsidies have been used to promote technology development and diffusion. Similarly, the EC has promoted collaborative R&D under the Framework Program. The Framework Program is scheduled to allocate $8.4 billion between 1990 and 1994.

Nevertheless, not all collective research efforts in Japan and Europe, particularly those subsidized by the central government, have been successful. Despite years of effort, Japan has failed to gain a major foothold in the U.S.-dominated pharmaceutical industry. Similarly, Europe's heavily subsidized electronics industry has failed to close the gap with the United States. Therefore, "heavy-handed industrial policy," where the government picks technological winners and losers, is not the answer (Cohen and Noll, 1991; National Academy of Sciences, 1992).

An argument can be made for public support of pre-commercial R&D when private industry, acting in response to market incentives, underinvests in socially desirable projects (e.g., Alston, 1992; Arrow, 1962; Cohen and Noll, 1991). Private sector underinvestment can occur due to the following types of market failure:

(1) Appropriability: A firm cannot appropriate all of the benefits from its R&D investments because others can "free-ride" on the public goods produced as a result of its initial R&D;

(2) Externalities: An individual's production or consumption activities affect another person's production or consumption and those impacts are not compensated through a market transaction;

(3) Public sector benefits: The benefits of the R&D are localized in the public sector; and

(4) Risk aversion and financial market failures: A firm may value near-term payoffs more highly than society, thus leading to an underinvestment in activities that take a relatively long time to pay off, and/or a firm may be overly risk averse as compared with the best interests of society.

Appropriability

Appropriability becomes an issue when R&D involves the promise of useful new knowledge that is generic, with wide applications across economic activities. Generally, private goods can be sold commercially and the benefits from their sale are captured by those who own the associated property rights or patents. In agriculture, this includes

[1] Sources are listed in the references section at the end of this article.

[2] R&D in this paper refers primarily to commercial projects. There are generally four stages in commercial R&D (Cohen and Noll, 1991).

RESEARCH: The first stage determines whether the basic ideas are technically sound. This exploratory research either "expands the base of fundamental knowledge or applies the existing base to some new set of problems;"

DEVELOPMENT: The second stage consists of "designing, building, and testing components and even small-scale versions of new technology." These types of activities are built on a firmer scientific base than research, and so the uncertainty is usually less;

DEMONSTRATION: This category refers to "the construction of an operating example of the new technology to prove its technical and commercial feasibility." Demonstration projects are usually the most expensive and they are unlikely to be attempted unless the uncertainties surrounding its performance are considerably less than those associated with the previous two stages; and

ADOPTION: The fourth category is when a private and/or public organization use the new technology.

hybrid seeds, which must be purchased each time a crop is planted. However, even the patent system is often ineffective in protecting property rights over information (Hay and Morris, 1979).

Nonetheless, appropriability is most often an issue with collective goods. By definition, collective goods do not lend themselves to profitable merchandising, even though there may be significant gains to society. Agricultural examples of collective goods include improved self-pollinated plants such as any new variety of wheat that, once released and sown, can be retained and used as seed for planting in subsequent years. Because private firms cannot capture all the benefits of producing collective goods, neither a socially optimal level of R&D nor a socially optimal amount of the goods will be produced.

Government support of R&D in collective goods in agriculture is extensive. In wheat, this includes basic research in seed genetics, applied research in the production of better varieties, demonstration projects to examine production in different climates, and adoption information provided by the agricultural extension service.

The problem of market failure is likely to be smaller for relatively applied/pre-commercial R&D than for basic R&D (Evenson and Huffman, 1989); however, pre-commercial R&D can exhibit appropriability problems (National Academy of Sciences, 1992). For example, "learning by doing" and other forms of imitation may drive the price of a product down, perhaps leaving an operating margin insufficient to recover the costs of the original R&D (Cohen and Noll, 1991; Frisvold, 1991). Additionally, much of the benefit of R&D is often passed on to customers and does not enter into the profitability calculation of the firm (Mansfield, 1980; Scherer, 1982). For these reasons, neoclassical economic theory does not weaken the case for Federal support of pre-commercial R&D, but it does require evidence of appropriability problems or some other form of market failure (Alston, 1992).

Externalities

Firms may also underinvest in pre-commercial R&D due to an environmental externality. The crucial feature of an externality is that there are goods or services that people care about which are not sold in markets (Varian, 1987; Baumol and Oates, 1988). For instance, there is no market for pesticide leachate, nor is there a market for environmentally sound farming practices. It is this lack of a definable market that requires government action.

In the case of a negative externality, the price system works too well (Kneese and Shultzie, 1975). Profit-motivated firms produce to that point where their marginal costs of production (private marginal costs) intersect demand. With a negative externality, private marginal costs do not incorporate all of the consumer costs associated with the disposal and use of a particular product (that is, social marginal costs). As a result, private marginal costs are less than social marginal costs, leading to overproduction from a societal perspective. In turn, this overproduction generates a deadweight welfare loss for society.

From an economic standpoint, the goal of regulation is to raise private marginal costs so they equal social marginal costs. In a world of perfect information, regulators could use almost any policy tool to ensure this outcome. Often, in reality, the best that can be done is to achieve a politically determined level of environmental quality at the least cost (Anderson, 1977). This objective can be reached with environmental taxes. Alternatively, if policy-makers are reluctant to increase taxes, government support of R&D may prevent an environmental externality from acting as a barrier to entry for products that are more "environmentally friendly."

For illustrative purposes, consider biodegradable plastics. Between 1960 and 1990 annual growth in plastic production averaged 10 percent, far greater than the annual growth in the overall economy (EPA, 1990). Unfortunately, increased plastic use has also resulted in increased plastic wastes. In a 1990 report, EPA was primarily concerned with the impact of plastic waste on solid waste management and on the marine environment. Plastics currently account for approximately 8 percent by weight and 20 percent by volume of the municipal solid waste stream (National Technical Information Center, 1992).

In addition, plastic waste in the marine environment often poses risks to marine life, human life, and aesthetic appearance. The Marpol Treaty, signed in 1987 by 29 countries including the United States, prohibits the discharge of all plastic wastes at sea beginning in 1988 for commercial vessels and in 1994 for government ships. In an effort to adhere to the treaty, the U.S. Army—in conjunction with the USDA and private companies—has implemented a large-scale effort to develop biodegradable polymers to replace petroleum-based plastics for all food uses.

Many of these polymers are being made from corn, wheat, and potato starch. The advantage of starch-based polymers is that they are fully degradable,

but their cost is generally greater than the cost of petroleum-based plastics (U.S. Army/USDA, 1992). For that reason, there is little incentive for firms to manufacture starch-based polymers. However, if the social marginal cost of starch-based polymers were lower than the social marginal cost of petroleum-based plastics, then the Government could improve resource allocation by subsidizing the production of starch-based polymers or taxing the production of petroleum-based plastics. Alternatively, the Government may prefer to support R&D to reduce the private costs of starch-based polymer production.

Public Sector Benefits

Firms may underinvest in pre-commercial R&D because the benefits are localized in the public sector. A technological breakthrough in the production, for example, of starch-based polymers would increase market demand for corn or wheat and reduce program payments with a minimal, yet, positive effect on total farm income (Leblanc and Reilly, 1988; Beach and Price, 1993).

Consider the generic commodity program shown in fig. 1. Initially, the target price is set at F, output is q, and government payments equal area FACP. Next, suppose there is a technological breakthrough in the production of starch-based polymers. This would shift the demand for program crops from D to D'. In this case, the demand shift has no effect on output, but it does reduce government payments to FABP'. Because total returns to producers are unchanged, farmers have little incentive to fund this type of demand-creating research (Frisvold, 1991). In comparison, the Government has a significant incentive, since demand-creating R&D would reduce the costs of farm income support programs.

Similarly, innovations in the use and development of new crops, which are economically viable alternatives to program crops, could also reduce the costs of farm income support programs. Consider the effect of a new crop on the commodity program shown in fig. 2. As in fig. 1, the initial target price is set at F, output is q, and government payments equal area FACP. The development of economically viable new crops which compete for program acres, excluding those acres in the conservation reserve program, would shift the supply curve for wheat or corn from S to S'. In this case, the quantity produced of program crops decreases from q to q', reducing government payments to FGHP'.

Risk Aversion and Financial Market Failures

Private firms may underinvest in pre-commercial R&D because the private discount rate may be too high relative to the social discount rate, leading to an underinvestment in activities that take a relatively long time to pay off. A related argument is that risk-averse firms may reduce R&D below the optimum social level (Arrow, 1962). This may happen because firms cannot transfer all of their R&D risks to shareholders, or because shareholders may not be persuaded to buy additional shares, or because all the incentives to the firm would be removed if all risks were shifted to

Figure 1
A Generic Farm Commodity Program

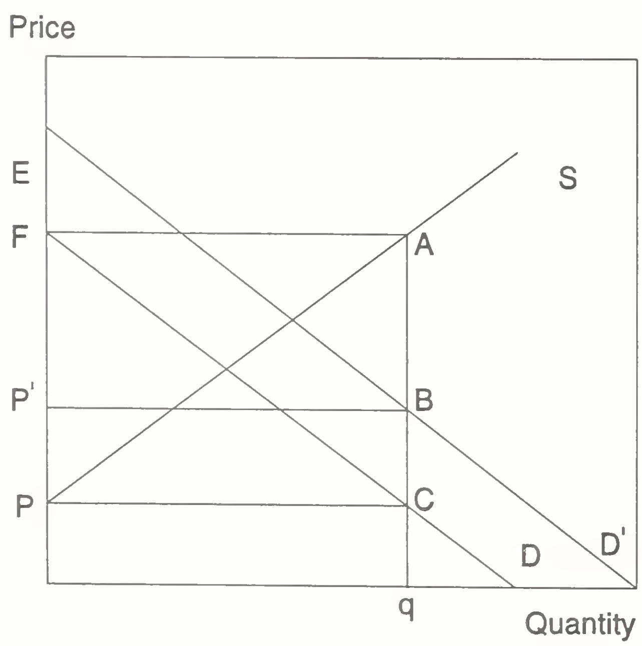
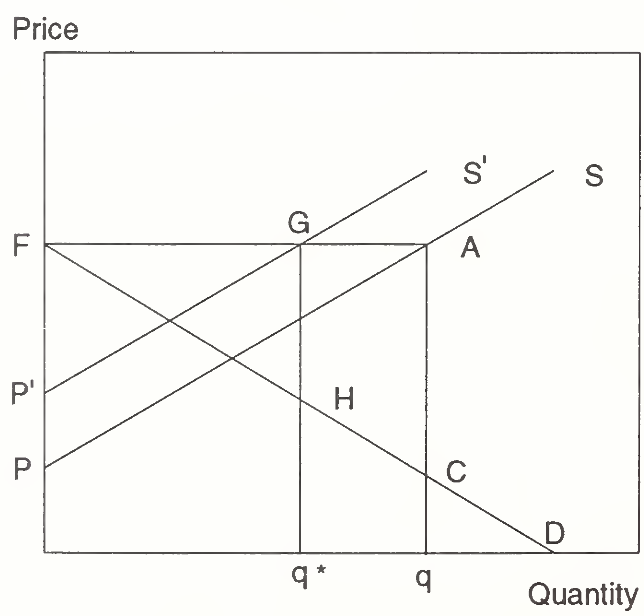


Figure 2
Introduction of a New Crop Given a Generic Farm Program



shareholders—that is, moral hazard. While the effect of risk in R&D investment is mitigated by a firm's ability to finance investments out of retained earnings, the extent of the risk effect is an empirical consideration. Neither of these reasons have been substantiated empirically.

Furthermore, U.S. government policies tend to support investments with high short-term payoffs relative to the economies of Japan and Germany (Harrison, 1992). Some argue that the problem of "short-termism" in the United States is a result of too little government support, whereas others argue that the problem is too much government intervention (anonymous, 1992). Regardless, both sides agree that short-termism cannot be averted by letting the government pick technological winners and losers.

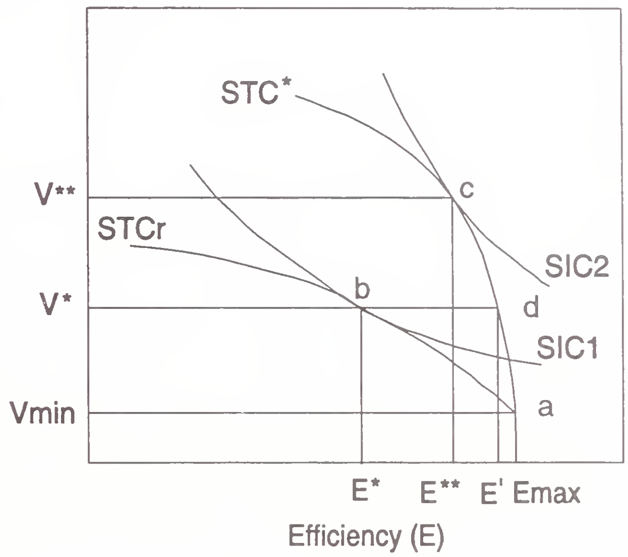
Setting Research Priority

In the economics literature, substantial progress has been made in analyzing the *ex post* benefits of R&D. However, more work needs to be done to develop a logical, comprehensive system to evaluate the *ex ante* benefits from R&D. Norton, Pardey, and Alston (1992) believe that three issues have proven particularly troublesome in *ex ante* priority setting: specifying the weights given multiple objectives, measuring research performance against those objectives, and combining the weights with measures of performance.

The desire to prioritize all research programs, even when their impacts are difficult to quantify, often leads to a simple weighting across rankings of crude indicators. As a result, program directors, policymakers, and the like are frequently confronted with a set of multiple and poorly identified objectives. This makes it difficult to derive rigorous performance measures, and hence place weights on the indicators at hand. In addition, economists have not solved many of the measurement problems, and many of the solutions they have suggested are data- and time-intensive. Perhaps a more fundamental problem is that the comparative advantage of sponsored research relative to other policy instruments has not been examined, nor have economists examined the possibility of combining sponsored research with some other policy instrument to enhance social, economic, and other societal objectives.

In figure 3 we consider some of these tradeoffs. The economics literature has traditionally used a social welfare function (SWF) to specify preferences among multiple social objectives. Fig. 3 examines the simplest case of multiple objectives—the case of two objectives. Following Norton, Pardey, and Alston (1992) we examine the tradeoff between economic efficiency (E) and equity (V).

Figure 3
Economic Efficiency with Two Social Objectives



Let curve STCr represent the best possible combinations of economic efficiency and equity that can be achieved by varying the mix of a research portfolio only. If the research portfolio were chosen to maximize economic efficiency (Emax) then point (a) would be the result. Next, let curve SIC1 represent policymakers' willingness to substitute equity for economic efficiency. The highest level of social welfare through changes in the research portfolio, given policymakers' willingness to substitute equity for efficiency, occurs at (b) where SIC1 is tangent to STCr.

Last, let STC* represent those combinations of economic efficiency and equity that are possible by adding a second policy instrument, such as a tax, to the mix of the research portfolio. In this case the optimal outcome is point (c) where the production frontier STC* is tangent to the relevant indifference curve SIC2. Clearly, (c) represents higher levels of both equity (V**) and efficiency (E**), than point (b). This occurs because the research-policy approach combines research and nonresearch instruments in a more efficient way than pursuing the equity objective through research alone.

It is possible to reach STC* with a smaller loss in economic efficiency, yet retain the efficiency level of the research approach (V*). Point (d) represents an intermediate solution between the free market outcome (a) and the combined research/tax program outcome (c). The efficiency loss from the

combined program is (E**), and it is (Emax - E') at point (d). This gives a net gain in efficiency of (E' - E**), with a loss in equity of (V** - V*).

Fig. 3 demonstrates the need for economic analysis in identifying the tradeoffs involved in using research policy as an instrument of social policy. While economics alone cannot indicate the least-cost way of achieving non-efficiency objectives, evaluating past investments, assessing alternatives, and setting priorities for future investments are economic problems. Therefore, economists must work with those scientists and engineers doing pre-commercial R&D to help insure the most efficient use of our limited resources (Alston, 1992).

Scoring Models

Multiple and poorly identified objectives, measurement errors, and other associated problems can hamper policymakers' search for practical evaluation procedures. For that reason, peer review systems can be a cost-effective alternative to the overly quantitative priority-setting procedures suggested by some economists. Peer review systems are especially attractive in evaluating different projects and determining their contribution to the overall program.

Scoring models are often used to organize peer review discussions, reduce subjectivity, and bring the objectives of the program to the forefront. Strengths of scoring models include (Shumway, 1973; Shumway and McCracken, 1975):

- a basic simplicity and favorable error characteristics (in a statistical sense) as compared to other more sophisticated decision models;
- the identification of a small number of criteria which, when properly related, will help evaluators choose between alternative projects;
- the development of a discrete scale for each criterion with sufficient range for all relevant alternatives and only enough intervals to discriminate between those that differ significantly;
- the formation of a set of both qualitative and quantitative criteria provided that each is independent of the others;
- the incorporation of decision criteria to reject automatically, or segregate for separate evaluation, a project which falls outside the acceptable range; and
- the relative score of each criterion can double as an information system, thus permitting evaluators to identify areas of relative weakness and encouraging researchers to consider alternative approaches.

On the other hand, scoring models are not very useful in determining the distributional effect of "aggregate research." Scoring models are also unable to quantify public sector/private sector interaction and spillover effects. Lastly, scoring models do not provide estimates of the marginal rate and average rate of returns to research (Norton and Davis, 1981). Nevertheless, under a program like the AARC Center, a scoring model may be the most cost efficient approach to evaluate project proposals.[3]

Traditional Economic Welfare Analysis

As suggested above, a scoring model is ill-prepared to answer the more difficult question of the likely effect of pre-commercial R&D on the size and distribution of national income. From a theoretical perspective, the positive economic aspects of this question can be addressed by using economic welfare analysis. As suggested by Harberger (1971, p. 785), there are three basic postulates that should be accepted as providing a conventional framework for welfare analysis:

(1) the competitive demand price for a given unit measures the value of that unit to the demander;

(2) the competitive supply price for a given unit measures the value of that unit to the supplier; and

(3) the net benefits or costs of a given project, program, or policy accruing to each affected individual should be added without regard to that individual's economic or social status.

For example, consider the effect of a technological breakthrough in the use of agricultural products as materials in manufacturing. Given the initial demand and supply curves, total surplus can be measured as the sum of consumer and producer surplus (Harberger, 1971). A breakthrough in the use of agricultural materials in manufacturing would shift the demand for agricultural products

[3]Scoring models can incorporate efficiency criteria by including factors related to both the execution of a research project and the selection of a project mix. In fact these factors should be included because, as Cohen and Noll (1991) observe, "whatever the objectives of the decisionmakers are, efficiency is almost always going to be a useful instrument for achieving them."

outward. As a result, producers would necessarily gain because they would sell more goods at a higher price. In comparison, the net welfare effect on consumers may be positive or negative depending on the elasticity of supply and demand, and on the nature of the research-induced demand shift.

Because many of the projects being considered by the AARC Center involve new markets or at least new market niches for existing products, the data necessary to make economic surplus calculations are not available.[4] Therefore, as mentioned above, a scoring model may be the most cost efficient approach to evaluate project proposals for the Center. Still, it is misleading to cast scoring methods as an alternative to economic surplus (Norton, Pardey, and Alston, 1992). Clearly, economic welfare is one of their most (if not the most) important objectives. The bottom line is that when economic surplus measures are available they should be incorporated as data in any scoring method procedure. In contrast, when economic surplus measures are not available, then one should recognize that economic surplus is implicit in all scoring approaches. For that reason, scoring models should not be regarded as an alternative to economic surplus; but, rather, scoring models complement more complex evaluation procedures based on *ex ante* estimates of economic surplus.

Review of Selected Research Programs with Similar Objectives

If programs were economically rational and designed with a single objective, then from an economic standpoint, the only data needed to evaluate a particular set of projects would be measures of:

- the size of the relevant market;
- the percentage shift of supply or demand;
- the probability of success;
- the time path of adoption of results;
- the time path of costs; and
- the discount rate (Alston, 1992).

None of the programs reviewed here has a single, simple objective.

The biofuels program at USDA's Office of Energy (OE) is quite close. The stated goal of the biofuels program is to develop technologies to produce commercially competitive liquid fuels from biomass as an alternative to petroleum based fuels. This single goal with closely related objectives allows OE to use a simple formula to rank alternative projects:

$$\text{Net ranking} = P * NB * e^{-rt}$$

where P is the probability of success; NB is the total net benefit discounted to the first year of commercial operation; t is the number of years to adoption; and r is the discount rate (Kuhn and Rendleman, 1992). This equation can also be used to obtain an ordinal ranking of projects, rather than a cardinal ranking. It is particularly useful to compare tradeoffs. However, when multiple objectives are specified, as in the AARC legislation, using simple formulas to rank proposals is often misleading.

The Advanced Technology Program (ATP) is a new effort, administered by the National Institute of Standards and Technology of the Department of Commerce and designed to assist businesses in carrying out research and development of precompetitive, generic technologies. Like the AARC Center, the ATP faces multiple objectives in a complex dynamic environment. To circumvent many of the difficulties associated with multiple objectives, the ATP uses a peer review system based upon a multi-stage scoring method to evaluate and select projects to fund. The evaluation criteria and sub-criteria are shown in table 1.

Under the ATP, the Department of Commerce has stated a bias for projects with high risk and potentially high payoffs. They are able to take these risks given a comparatively large budget. Since 1990, 38 projects were funded at over $100 million (Technology Access Report, 1992). Also, legislation was introduced last year to elevate funding for the ATP to a total of $1.4 billion for 1994-1998. In comparison, a $4 million annual budget and a goal to be self-funding prevents the AARC Center from financing too many high-risk projects.

An alternative evaluation scheme proposed by Fernandez-Cornejo is closer to the economic fundamentals necessary for the AARC Center to be self-sufficient (See table 2).[5] This scheme promotes a diversified portfolio of projects by limiting the size of each project to less than 25 percent of the total budget. This method also emphasizes the need to avoid duplication and capitalize on each partici-

[4]As a reviewer observed, traditional welfare analysis may not be very helpful given the dynamic nature of technical change and the deviations from perfect competition (Nelson, 1982) created by the patent system and exclusive licensing agreements between public and private agents.

[5]The evaluation procedure written by Fernandez-Cornejo was submitted as a proposal to the Research and Technology Division of the Economic Research Service and does not represent USDA official policy or views.

Table 1—ATP Evaluation Criteria

Criteria	Sub-Criteria
Scientific and Technical Merit	• Quality and degree of innovation of the proposed technical program • Appropriateness of the technical risk and feasibility of the project • Coherency of technical plan and clarity of vision of technical objectives • Adequacy of systems-integration and multi-disciplinary planning including integration of appropriate downstream or upstream production, manufacturing, quality assurance, and customer service requirements
Potential Broad-based Benefits	• Potential broad impact on U.S. technology and knowledge base • Potential to improve U.S. economic growth and the productivity of a broad spectrum of industrial sectors or business • Timeliness of the proposal (i.e., the potential project results will not occur too late to be competitively useful)
Technology Transfer Benefits	• Evidence that if the project is successful, the participants will pursue further development of the technology toward commercial application • Project plan adequately addresses technology transfer requirements to assure prompt and widespread use and protection of results by participants and as appropriate, other U.S. business
Experience and Qualifications	• Adequacy of staffing, facilities, equipment, and other resources to accomplish the proposed program objectives • Quality and appropriateness of the full-time technical staff to carry out the proposed work program and to identify and overcome technical barriers to meeting project objectives
Level of Commitment and Organizational Structure	• Level of commitment as demonstrated by contribution of personnel, equipment, facilities, and matching funds • Evidence of strong commitment to complete and, if appropriate, provide support for continuation beyond the period of federal funding • Potential return to the U.S. government

pant's comparative advantage. With tighter budgets at all levels of government, public agricultural research systems must avoid duplication whenever possible and ensure that a proposed project, if worthwhile, cannot be more efficiently carried out in other parts of government. Lastly, by multiplying the scores of each factor together, this method achieves balance among criteria and reinforces the argument that one criterion is of little value unless accompanied by relatively high scores on all other criteria.[6] However, for this method to be useful for the AARC Center it needs a more specific technical evaluation.

The Technical Advisory Committee to the Consultative Group for International Agricultural Research (CGIAR) proposed a modified scoring method to allocate the $250 million CGIAR annually provides to support agricultural research relevant to developing countries. TAC's scoring method uses a spreadsheet format to force relative adjustments across priorities. The economic logic of the approach is that, other things equal, the greatest returns to research should result from allocating resources to those commodities of highest value. Nevertheless, as mentioned above, economic efficiency criteria may not reflect concerns about income distribution, equity, externalities, long-run resource degradation, and other similar concerns. To overcome these problems TAC suggested a modified baseline in which the value of production and the number of poor and usable land areas were equally weighted and indexed. In TAC's view the composite baseline represents a better beginning point for its analysis given CGIAR's mission (McCalla and Ryan, 1992).

The advantages of the spreadsheet scoring model are its transparency to both scientists and decisionmakers and its structure, which allow multiple decision variables to be accommodated. The disadvantages include a difficulty in arriving at a consistent pattern of research at disaggregated levels and an untractable system when resource constraints are introduced. Additionally, TAC's spreadsheet model is extremely sensitive to changes in the selected weights (McCalla and Ryan, 1992).

The Proposed Method to Evaluate AARC Center Proposals

As stated earlier, the legislation establishing the AARC Center provides a peer review process, to

[6]Our multiplicative scoring model is consistent with an underlying multiplicative research production function (such as the Cobb Douglas or translog functions). However, given the subjectiveness of each factor considered (inputs in the research production function) it was decided to use a simple weighing procedure with no interaction terms.

Table 2—Evaluation of Cooperative Agreements

Factor	Value
Contribution of project objectives to Agency's mission	0,1,2,3,4,5 (low - high)
Contribution of methodology to achieve project objectives	0,1,2,3,4,5 (low - high)
Likelihood that methodology will be carried out as planned	Continuous variable ranging from 0 (unlikely - data will not support methodology, model is not well grounded, research is totally unknown) - to 1 (certain - data is available and will support methodology, model is well grounded, researcher is well known)
Overlap, duplication, complementarities with other projects	0 duplicates other projects 1 moderate overlap 2 small overlap 3 no overlap 4 small complementarities with other projects 5 important complementarities with other projects
Cooperative venture or is agency financing the project	Continuous variable ranging from 0 (agency solely financing) to 1 (cooperative venture, clearly specified in the proposal).
Comparative advantage	0 agency has a large comparative advantage 1 agency has a moderate comparative advantage 2 cooperator and agency have similar comparative advantage 3 cooperator has a moderate comparative advantage 4 Cooperator has a large comparative advantage
Cost	0 budget is over 25% of total allotment for all agency projects 1 cost seems too high/low 2 cost seems right

help ensure the technical, scientific, and economic feasibility of each funded project and to help insure that the best interests of society are duly represented. From an economic perspective, the peer review process needs to establish that:

1) each funded project meets a minimum level of technical or scientific merit; and

2) each funded project demonstrates that the private sector, acting in response to market incentives, would underinvest in the research, development, and/or commercialization of the project.

Recall that private sector underinvestment, from a national viewpoint, can occur due to (a) appropriability problems, (b) externalities, (c) benefits which are localized in the public sector, and (d) financial market/risk considerations. Because there is mixed theoretical and empirical support for (d), we encourage the AARC Center to give priority to those proposals which fall in one or more of the first three categories.

We propose a three-phase scoring method designed to help guide the evaluation of proposals submitted to the AARC Center. The first phase involves an initial screening of pre-proposals to insure compliance with the basic program.[7] The principal investigators of those pre-proposals which meet the basic requirements, as set up in the request for pre-proposals, are asked to prepare a more complete proposal in phase 2.

In phase 2, experts would evaluate each proposal for scientific/technical merit and for evidence of private-sector underinvestment. Review panelists (Panel I) would be selected from among recognized specialists who are uniquely qualified by training and experience in their fields. Panel I would be comprised of experts from universities, government, and nonprofit research organizations.

Each member of Panel I would review in depth at least three proposals. Each proposal would be reviewed by three reviewers and scored according to the four categories and nine criteria listed in table 3. The score provides a relative ranking among projects and enables panel members to decide which rating fits the project. The total score is obtained by calculating the geometric sum of the scores of all nine criteria. Thus, a balance between criteria is established. In addition, the method

[7]In the future, Phase 1 could also include a screen to divide the projects by subject and by size of request. This can be used to promote diversity and reduce the risk of funding only large/small projects or the risks of funding projects in one subject area.

Table 3—Phase 2 Evaluation Criteria

Technical Review Criteria	Description	Score
A. Assessment of Technology		
Scientific and Technical Merit	• Quality and degree of innovation of the proposed technical program • Coherency of technical plan and clarity of vision of technical objectives	3 high merit 2 intermediate merit 1 low merit 0 no merit
Adequacy of Approach and Excellence of Research Procedure	• Research plan is scientifically feasible • Proposed methods and equipment are appropriate and sufficient to accomplish the objectives	3 highly adequate 2 adequate 1 slightly adequate 0 inadequate
Overlap, duplication, complementarities with other projects	• Proposed research does not substantially duplicate any ongoing or previous research but rather is complementary to other research. • Proposed research would enhance benefits of total portfolio	5 important complementaries 4 small complementarities 3 no overlap 2 small overlap 1 moderate overlap 0 complete overlap
B. Assessment of Project		
Capability of Key Personnel	• Identified personnel have the necessary background and skills to successfully complete the project	3 highly capable 2 capable 1 questionable capabilities 0 incapable
Project Design	• Project has been conceived and organized in a manner appropriate for achieving the desired results	3 excellent design 2 good design 1 adequate design 0 poor design
C. Evidence of Market Failure	• Private firms cannot appropriate all the benefits of R&D • Evidence of externalities • R&D benefits are localized in the public sector	1 evidence of market failure 0 no evidence of market failure
D. Feasibility and Efficiency		
Probability of Success	• Objectives can be accomplished • High Probability of success in light of past accomplishments and performance	3 high probability 2 intermediate probability 1 low probability 0 zero probability
Efficiency of execution	• Project is likely to be executed efficiently, within the stated time period and budget	1 efficiently executed 0.5 medium efficiency 0 inefficiently executed
Comparative Advantage	• Principal Investigator (PI) has a comparative advantage in carrying out the pre-commercial R&D • Proposed R&D is not likely to be completed as successfully and efficiently at a USDA research facility	4 PI clear comparative advantage (ca) 3 PI moderate ca 2 PI and USDA similar ca 1 USDA moderate ca 0 USDA clear ca
Cost	• Project promotes a diversified portfolio of AARC funded activities	2 cost seems right 1 cost seems too high/low 0 budget is over 25% of total budget for all projects

reinforces the assumption that a high score on any one criterion is of little value unless it is accompanied by relatively high scores on all other criteria (See footnote 2). The score sheet also provides additional information on areas of relative strength and weakness of each project.

Next, each member of Panel I would lead a discussion of one proposal to the rest of the panel. The other two panel members who have read the proposal would be asked to support or challenge the statements of the lead reviewer. Each panel member would write an evaluation of the proposals

he/she has read. The lead reviewer would write a summary of the discussion that led to the rating by the full panel. Projects would be rated by a consensus of the full panel, as

- recommended highly;
- recommended with comments: the project will be approved after some identified changes;
- recommended conditionally: the project has met some but not all of the criteria, leaving some serious deficiencies which must be corrected before approval can be granted; or
- rejected.

Panel II should be comprised of reviewers with expertise in business planning, finance, and technology transfer. The makeup of Panel II should be similar to the AARC Board.

Only those principal investigators with proposals that were "recommended highly" or "recommended" in phase 2 should be evaluated in phase 3. Each member of Panel II would read all proposals and review in depth at least three proposals. As in phase 2, each member would discuss in depth at least one proposal in front of the full panel, while the other two panel members who have scored the proposal are asked to support or challenge the statements of the lead reviewer. The lead reviewer would summarize the discussion of the full panel.

Phase 3 criteria are displayed in table 4. The highest ranked proposals from phase 3 would be designated as semifinalists and their ranking would be submitted to the board.

Last, the principal investigators from those institutions which are designated as semifinalists in phase 3 would then be asked to make an oral presentation to the Board. Because all the pro-

Table 4—Phase 3 Evaluation Criteria

Criteria	Description	Score
A. Economic Impact		
Market/Market Share	• Product/service has the potential to significantly affect the market • Product/service can gain a significant market share	3 high market impact 2 intermediate market impact 1 low market impact 0 no market impact
Commercialization Plan	• Timeliness of the proposal (i.e., the potential project results will not occur too late to be competitively useful) • Project plan is adequate to transfer technology from the laboratory to the plant floor or marketplace • Project adequately addresses technology transfer requirements to assure prompt and widespread use	3 excellent plan 2 good plan 1 poor plan 0 inadequate plan
Job Creation	• If successful, the project will create a significant number of geographically dispersed jobs (direct and indirect), relative to the project estimated revenues	1 significant creation 0.5 small creation 0 negligible creation
B. Level of Commitment		
Evidence of Commitment	• Evidence of strong commitment to complete and, if appropriate, provide support for continuation beyond the period of federal funding	3 strong evidence 2 evidence 1 little evidence 0 no evidence
Project Budget and Level of Private Sector Funding	• Level of commitment as demonstrated by contribution of personnel, equipment, facilities, and matching funds • Overall financial support is appropriate for the tasks presented and demonstrates an understanding of the issues and problems likely to be encountered • Proposal shows an awareness of anticipated financing needed to bring the product to market	2 adequate funding 1 moderate funding 0 inadequate funding
Management	• Appropriate management structure is identified to facilitate business growth	3 excellent structure 2 good structure 1 poor structure 0 inadequate structure

posals that are designated as "semifinalists" in phase 3 meet all technical and economic criteria, the final decision would be based upon:

- the availability of funds, and
- an appropriate distribution of funds among technologies and their applications (this will insure a diversified portfolio of funded projects).

Conclusion

An argument can be made for government support of research and development (R&D) when private industry, acting in response to market incentives, underinvests in socially desirable projects. Private sector underinvestment, from a national viewpoint, can occur due to appropriability problems, externalities, benefits localized in the public sector, and financial market/risk considerations.

The AARC Center was mandated by Congress to support pre-commercial R&D in new industrial uses of agricultural commodities. To help ensure success, Congress also provided for a peer review process to evaluate AARC Center proposals. In turn, peer review needs to establish that: (a) each funded project meets a minimum level of technical/scientific merit; and (b) each funded project is based on evidence that the private sector, acting in response to market incentives, would underinvest in the research, development, and commercialization of projects that are socially desirable.

Scoring models are often used to organize peer review discussions and bring the objectives of the program to the forefront. This paper develops a three-phase scoring model to evaluate the proposals for the AARC Center. The first phase involves an initial screening of pre-proposals to ensure compliance with the basic program. Those pre-proposals that met the basic requirements are contacted for a more complete proposal in phase 2. In phase 2 scientific, technical, and economic experts (Panel I) would evaluate each proposal for scientific/technical merit and for evidence of private-sector underinvestment. Only those pre-proposals that are "recommended highly" or "recommended with comments" would be evaluated in Phase 3.

Phase 3 reviewers (Panel II) should have a demonstrated expertise in business planning, finance, and/or technology transfer. The highest ranked proposals in Phase 3 are designated as semifinalists and their ranking submitted to the Board. The principal investigators of those proposals would then be asked to make an oral presentation to the AARC Board. Funding decisions would then be made by the Board.

Appendix: The Alternative Agricultural Research Center

Title XVI, subtitle G, of the 1990 Farm Bill provides government support for the AARC Center. The stated purpose of the AARC is:

- to develop and produce marketable products other than food, feed, or traditional forest or fiber products;
- to commercialize new nonfood, nonfeed, uses ...; and
- to direct ... research and commercialization efforts toward ... agricultural commodities that can be raised by family-sized agricultural producers.

The AARC Center is led by a Board of nine members, appointed by the Secretary of Agriculture. The Board consists of one USDA representative, one leading scientist, a producer of agricultural commodities, a person engaged in the commercialization of an industrial product from an agricultural material, two nominations by the Director of the National Science Foundation of persons with expertise in processing and/or applied research relating to the commercialization of industrial products from agricultural materials, and two nominations by the Secretary of Commerce of persons who have demonstrated expertise in financial and management matters.[8] The AARC Board's responsibilities include:

- establishing policy and program direction;
- determining high priority areas to receive assistance;
- issuing requests for proposals; and
- making final decisions on whether and how to provide financial assistance (AARC Center Program Pamphlet).

The AARC Center may provide financial assistance in the form of loans, interest subsidy payments, venture capital, and repayable grants that are

[8]Issues such as trade-offs in the composition of the Board, i.e., the value of having the industry's input and experience versus the cost of having a possible shift in the direction of research as discussed by Ulrich, Furtan, and Schmitz (1986) are beyond the scope of this paper.

matched by private or local public funds. The AARC Board may also

> "establish one or more temporary committees with agricultural, scientific, technical, or other expertise, whose duties shall be to provide information, analysis, and recommendations, ... on scientific, technological, policy, and other matters ... (section 1658, subtitle G of section XVI of the 1990 Farm Bill).

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Estimating the U.S. Demand for Sugar in the Presence of Measurement Error in the Data

Noel D. Uri

Abstract. *Inaccuracy in the measurement of the price data for the substitute sweeteners for sugar is a problem encountered in the estimation of the demand for sugar. Two diagnostics are introduced to assess the effect that this measurement error has on the estimated coefficients of the sugar demand relationship. The regression coefficient bounds diagnostic is used to indicate a range in which the true price responsiveness of consumers to changes in the price of sugar substitutes lies. The bias correction factor is computed to evaluate the magnitude of the overestimation of the responsiveness of the quantity of beverage sugar and nonbeverage sugar demanded to a change in the price of sugar.*

Keywords. *Sugar demand, random measurement error, price responsiveness, beverage sugar, nonbeverage sugar*

Both policy analyses such as that found in General Accounting Office (1993)[1] and the studies cited therein and forecasting efforts such as that found in Economic Research Service (various issues) rely on estimates of the demand for sugar. The implicit assumption in these efforts is that the sugar demand relationships are accurately estimated and that the responsiveness of the quantity demanded to changes in the price of sugar is adequately calibrated. In what follows, this presumption will be examined by looking at the impact that errors in the measurement of one of the explanatory variables has on the estimated relationships of the demand for sugar. The implications of this for sugar policy analyses and forecasting will be assessed.

There are a variety of reasons why the estimates of the demand elasticities for agricultural commodities are frequently tenuous. Foremost among these are the differences in economic and institutional conditions reflected in the data and the differences in estimation procedures applied to the data to derive the estimates. Differences associated with the data are frequently easy to identify and comprehend. Estimates vary between studies because the magnitudes of the variations in the data and the behavior of the observed variables are different.

Differences that arise due to the variations in the estimation procedure are more difficult to identify. Well conceived empirical studies of demand begin with the same basic economic notions. That is, they are all based on conventional neoclassical microeconomic theory. It is the functional specification and estimation procedure that produces divergence. A choice must be made about the type of model to use, the sorts of data that are appropriate, and the estimation procedure to be employed in fitting the data to the model. In making these choices, a number of estimation problems are either explicitly or implicitly addressed. These include how data are aggregated across individuals, the choice of the functional form(s) considered, the nature of the dynamic relationship between price and quantity demanded, and the way the influences impacting demand are separated. (Griliches, 1986, explores these and other issues in greater detail.)

One concern that encompasses both the differences in economic and institutional conditions reflected in the data and the differences in estimation procedures, and one that has received little attention in previous attempts to model the demand for agricultural commodities, involves the presence of random errors associated with the measurement of the variables needed to properly estimate a demand relationship. Random measurement error occurs when the measured values of a variable are sometimes greater than and sometimes less than or equal to the true or accurately measured value. With random measurement error, the economic and institutional conditions that should be reflected by the data are inaccurately portrayed. This, in turn, has consequences for the actual estimates. These will be explored. Before doing so, however, a demand model, which will be used to assess the impact of random measurement error, is presented. Sugar is the commodity used in the analysis.

Modelling the Demand for Sugar

Overview

In the short run, the demand for sugar is presumed to follow a flow-adjustment process of

Uri is an agricultural economist with the Commodity Economics Division, ERS. He thanks the anonymous referees for helpful suggestions.

[1]Sources are listed in the References section at the end of this article.

the Houthakker-Taylor type (Houthakker and Taylor, 1970). In this sort of model, the tastes of consumers and considerations such as the availability of substitutes, the degree of substitutability of alternative sweeteners for sugar and health and nutrition factors are assumed to be fixed in the short run and consumption of sugar is presumed to be entirely a function of normal economic influences such as prices and disposable personal income. In this situation a classical adjustment model can be used. Assume that there is a desired demand Q_t^* for sugar by consumers at time t. This demand is a function of the price of sugar and a vector of other relevant economic and institutional variables, X_t.

In general functional form,

$$Q_t^* = f(P_t, X_t). \quad (1)$$

This level of demand is reached only in conditions of long run equilibrium. A simple adjustment process is assumed whereby

$$(Q_t - Q_{(t-1)}) = a(Q_t^* - Q_{(t-1)}) \quad (2)$$

where the adjustment parameter a is between zero and one. (The choice of this specification for the adjustment process will be discussed below.) Hence, actual demand for sugar in the current period, Q_t, is given by

$$Q_t = a(Q_t^*) + (1-a)(Q_{(t-1)}). \quad (3)$$

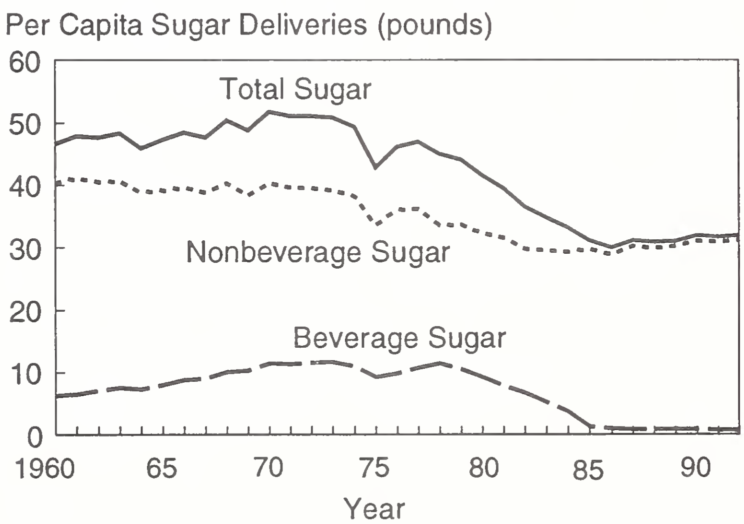
Demand Specification

The empirical analysis will focus on just two categories of sugar demand—beverage sugar and nonbeverage sugar.[2] The quantity of sugar demanded per capita by these two categories over the period 1960-1992 is shown in fig. 1.[3]

Beverage sugar demand is a derived demand. That is, the demand for beverage sugar is not based on any intrinsic desire for the sugar itself, but rather on the need to use the sugar to sweeten the beverages which are in turn sold to final consumers or to wholesalers and retail establishments who then sell them to final consumers.[4] This means that the demand for beverage sugar is determined in the final markets by the demand and supply for the beverage products being sold. Thus, the derived demand for sugar is indirectly based on the elements which generate the supply and demand for the final beverage products. In a properly specified demand model for beverage sugar, these factors must be either explicitly or implicitly taken into account.

Nonbeverage sugar is a fairly heterogeneous category. Some components of this demand are derived and some consist of demand by final consumers. Thus, for example, the demand for sugar for ice cream and dairy products, canned, bottled and

Figure 1
Per Capita Quantity of Sugar Consumed in the United States in Pounds: 1960-1992



[2]Two separate categories of sugar consumption are considered here: sugar used in beverages (primarily soft drinks) and sugar for nonbeverage uses, including bakery, cereal, and allied products, confectionery and related products, ice cream and dairy products, canned, bottled, and frozen foods. This disaggregation is necessitated because sugar used for beverages has been the major contributor to the observed erratic behavior in aggregate sugar consumption. Between 1960 and 1969, beverage sugar accounted for around 25 percent of total [per capita] sugar consumption. In fact, the growth in beverage sugar consumption accounted for all of the aggregate growth in sugar consumption since the average nonbeverage sugar consumption per capita over the period was essentially static (that is, no statistically significant growth trend is evident). During the period 1970 to 1978, while per capita beverage sugar consumption exhibited, on average, no change from one year to the next, the decline in nonbeverage per capita sugar consumption accounted for the decline in aggregate per capita sugar consumption. Next, the big decline in total per capita sugar consumption between 1978 and 1985 is primarily an artifact of the precipitous decline in per capita beverage sugar consumption. Over this period, beverage sugar consumption declined at an average annual rate of 25.58 percent. Since 1985, per capita beverage sugar consumption has continued to decline but this has been more than offset by the increase in consumption of nonbeverage sugar of approximately 0.90 percent per year. This resulted in the modest growth in aggregate per capita sugar consumption between 1985 and 1992.

[3]Per capita sugar consumption is the focus here since it is this unit of measure that has served as the basis of the analysis of many of the U.S. sugar demand studies performed (some of these are cited below) and it is also the common unit on which industry assessments of trends in sugar consumption are based (for example, F.O. Lichts, 1991-B; Morris, 1980; and Page and Friend, 1974). Finally, it is a convenient basis on which to forecast the demand for sugar since changes in sugar consumption are inexorably tied to changes in the population size (for example, Blamberg, 1992).

[4]Stigler (1966) explores the nature of derived demand.

frozen foods, and bakery, cereal, and allied products are, in general, all derived demand.[5] On the other hand, the nonbeverage demand for sugar via retail and wholesale grocery sales is a final demand by consumers.[6] It was decided not to consider each of these components of nonbeverage sugar separately because their respective shares of the total quantity of sugar demanded have, unlike beverage sugar demand, been relatively stable over the period 1960 through 1992 and because there is a dearth of different objective explanatory variables available for each of the components. That is, each of the separate components is specified to be a function of the same set of explanatory variables (for example, disposable personal income and population). While it might be of interest to know, for example, how the demand for sugar by confectionery and related products responded to a change in the price of sugar relative to how retail grocery sales responded, this does not aid in the objective of this study of explaining the aggregate variability in the demand for sugar.

Given the foregoing considerations for beverage sugar and nonbeverage sugar, the specification of the desired demand per capita, $Q_t{}^*$, for beverage sugar and nonbeverage sugar separately are given as:

$$Q_t{}^* = C_0 + C_1\ (P_{at}) + C_2\ (P_{ot}) + C_3\ (ECON_t) + (V_t) \tag{4}$$

where Q^* denotes the per capita desired quantity demanded for beverage sugar (nonbeverage sugar) by consumers,

P_a denotes the average price of sugar consumed,

P_o denotes an average composite price of substitute sweeteners for sugar,

ECON denotes a proxy variable for economic activity designed to capture the effects of changes underlying the derived demand and final demand on the desired quantity demanded (per capita soft drink sales for beverage sugar and disposable personal income for nonbeverage sugar),

V denotes the error term,

t denotes the time period, and

C_0, C_1, C_2, and C_3 are parameters to be estimated.

Combining relationship 4 with relationship 3, the equation to be estimated becomes

$$Q_t = a\ C_0 + (1\text{-}a)\ (Q_{t\text{-}1}) + a\ C_1\ (P_{at}) + a\ C_2\ (P_{ot}) + a\ C_3\ (ECON_t) + V_t. \tag{5}$$

The coefficient on the sugar price term, P_{at}, should be negative (following conventional neoclassical demand theory) indicating that an increase in the price will result in a decrease in the quantity of either beverage sugar or nonbeverage sugar demanded. Since other types of sweeteners are ostensibly substitutes for sugar in both beverage and nonbeverage uses, the coefficient estimate on the price of the other sweetener should be positive indicating that it is a substitute good for sugar. The coefficients on the soft drink sales (in the case of beverage sugar) and disposable personal income (in the case on nonbeverage sugar) should be positive suggesting that an increase in soft drink sales or disposable personal income will be associated with an increase in the consumption of sugar.[7]

Data

The specific time period used in the estimation covers 1960 through 1992 because comprehensive and consistent (that is, consistently measured) sugar consumption and price data are available for this period. The data are national aggregate annual time series. The data were obtained from a variety of sources. Data on the quantity of sugar consumed and the wholesale sugar price[8] were taken from the *Sugar and Sweetener: Situation and Outlook Report* (Economic Research Service, various issues) and its predecessor publications (variously titled) and the *U.S. Sugar Statistical Compendium* (Angelo and others, 1991), all of which were published by the Economic Research Service of the United States Department of Agriculture (USDA). The composite price of substitute sweeteners for sugar is computed as a weighted average of the prices of glucose corn

[5]In 1992, this category of nonbeverage sugar demand accounted for approximately 52 percent of the total quantity of sugar consumed in the United States (Economic Research Service, March 1993).

[6]The quantity of sugar demanded by these sources accounted for approximately 45 percent of total sugar consumption in the United States in 1992 (Economic Research Service, March 1993).

[7]Disposable personal income is a commonly used measure of consumer purchasing power and purchasing propensity in empirical analyses. A complete assessment of the relevant issues can be found in Intriligator (1978, Chapter 7) and in Phlips (1974).

[8]Both the wholesale and the retail sugar price were used in preliminary analyses. The empirical results exhibit no statistically significant difference at the 5 percent level when one price is used in deference to the other. The results when the wholesale price of sugar was used in the estimation are reported here.

syrup, dextrose, and high fructose corn syrup (both 42 percent and 55 percent).[9,10] This price series was computed based on data obtained from various issues of *Sugar and Sweetener: Situation and Outlook Report* and its predecessor publications. The data on soft drink sales were obtained from Moore and Buzzanell (1991) while the data on disposable personal income and population were obtained from the Economic Report of the President (1993). Per capita soft drink sales were computed by dividing total soft drink sales by the population. All of the price and income data are in constant 1987 dollars. The real values of these variables were obtained by deflating their respective nominal values by the gross domestic product implicit price deflator. This deflator was obtained from the Economic Report of the President (1993) as were the population data.

Preliminary Analyses

Before presenting the estimation results for the model developed here, several issues need to be addressed. The first factor to be considered involves the demand model formulation. In the model formulation, an adjustment specification is used for the desired quantity demanded whereby the difference between the desired quantity demanded in the current period and the actual quantity demanded in the previous period is hypothesized to adjust at some specific rate a. An obvious question is whether this specification is supportable based on the data. Additionally, an additive specification is used in deference to others that are available (for example, a multiplicative specification). Is there any reason to prefer one specification over another? Each of these issues was examined in preliminary analyses using a statistical test suggested by Davidson and MacKinnon (1981). First, the issue of whether there is an adjustment over time of the desired quantity demanded was examined. This was accomplished by defining the null hypothesis to be the specification where there is no adjustment parameter and the alternative to be the specification where there is an adjustment parameter. The results of the Davidson-MacKinnon J-test strongly suggest that there is in fact a lag of one period[11] in the adjustment between the desired quantity demanded and the actual quantity demanded for both beverage sugar and nonbeverage sugar demand.[12] This means that consumers do not completely adjust their consumption of beverage sugar and nonbeverage sugar within the current period to changes in sugar prices, the price of sugar substitutes, soft drink sales, and disposable personal income.

Next, the null hypothesis that the appropriate specification is a linear specification versus a linear-in-logarithms (which was the alternative hypothesis) was investigated. The test indicated for beverage sugar and nonbeverage sugar that the null hypothesis could not be rejected.[13] Consequently, the linear specification was used in the estimation for both beverage sugar and nonbeverage sugar.

A second factor considered concerns whether there is an identifiable substitution of other types of sweeteners for sugar. To investigate this, a test for directional causality was used.[14]

To determine whether changes in the composite price of other types of sweeteners impacted the quantity of beverage sugar and nonbeverage sugar demanded, current period consumption of beverage sugar (nonbeverage sugar) was regressed on eight lagged values of beverage sugar (nonbeverage sugar) consumption (corresponding to consumption in six previous periods). This gave the restricted estimates used in performing the causality test. Subsequently, current period consumption of bev-

[9]Measuring the price of a representative sugar substitute is very difficult. The degree of substitutability between glucose corn syrup, dextrose, and high fructose corn syrup (HFCS) is, for some uses, relatively low. Thus, for example, in the case of soft drinks, glucose and dextrose are not equivalent to high fructose corn syrup as sugar substitutes. However, using the price of a HFCS in the beverage sugar demand equation has its problems. HFCS (42 percent) was only introduced in 1967 while HFCS (55 percent) was introduced in the late 1970s. Consequently, the available series on HFCS do not cover the period of this study. The alternative is to use a shorter time period in the estimation. This, however, presents another set of shortcomings because the underlying structural demand relationships changed over time. In order to handle the peculiarities associated with this, the use of the longer time series is required. Uri (1993) explains and explores this in detail.

[10]It would also be desirable to include a price or price index for noncaloric sweeteners thereby providing an indication of the extent to which sugar is a substitute for non-caloric sweeteners. Unfortunately, no consistent and comprehensive data series over the period of this study (1960 to 1992) exist on the price of the various noncaloric sweeteners. Hence, they are omitted from consideration.

[11]Longer lags were also considered but they proved to be statistically insignificant. Also, lags on the various explanatory variables of up to four periods were considered. In no instance was a distributed lag of any of the explanatory variables indicated.

[12]The computed J-test statistic for a linear-in-logarithms specification was 4.34 while for a linear specification it was 5.23 for the beverage sugar demand equation. Corresponding values for the nonbeverage sugar demand equation were 4.33 and 5.41, respectively. The critical chi-square value at the 5 percent level is 3.84.

[13]The computed J-test statistic for the beverage sugar equation was 2.46 and the computed J-test statistic for the nonbeverage sugar equation was 3.08. The critical chi-square value at the 5 percent level is 3.84.

[14]A general discussion of the technique is contained in Uri and Boyd (1990).

erage sugar (nonbeverage sugar) was regressed on eight lagged values of beverage sugar (nonbeverage sugar) consumption (corresponding to consumption in six previous periods) and six lagged values of the price of the substitute sweeteners. This gave the unrestricted estimates. The relevant partial F-statistics were then computed. For the beverage sugar equation, the computed value was 7.33 while for the nonbeverage sugar equation the computed value was 6.81. The critical value at the 5 percent level is $F(6, 26) = 2.47$. Hence, it is possible to identify from the data being used in the estimation the substitution of other sweeteners for beverage sugar and nonbeverage sugar (separately). Thus, for example, there is an indication that in response to changing relative sugar and other sweetener prices (however slight that change might have been) that beverage sugar (nonbeverage sugar) was substituted for one of the other sweeteners when the relative price change favored sugar over the other sweeteners.

The demand equations for beverage sugar and nonbeverage sugar were fit to the time series data previously discussed. Ordinary least squares was used with correction for first order serial correlation (which was present (not surprisingly since time series data were used) for both equations) using the approach of Beach and MacKinnon (1978).[15,16] An instrumental variable was used for the lagged dependent variable (Bowden and Turkington (1984)). The instrument was defined to be a linear function of the average price of sugar, the average composite price of the substitute sweeteners for sugar, and the proxy variable for economic activity (soft drink sales for beverage sugar and disposable personal income for nonbeverage sugar) all in the current period. Lagged values of these variables did not enhance the fit of the relationship.

The initial estimation results were very poor. There were few statistically significant coefficient estimates and the coefficient of determination was below 0.50 for both the beverage sugar and the nonbeverage sugar demand equations. One of the reasons for this lack of acceptable results is that the demand for beverage sugar and the demand for nonbeverage sugar destabilized over the sample period. This destabilization coincided with the introduction of high fructose corn syrup (HFCS) as a new and relatively high intensity sweetener during the period of study.[17]

Estimation Results

The developments in the HFCS industry over the past 20 years or so coupled with the price advantage of HFCS over the domestic price of sugar[18] lead to HFCS having a destabilizing effect on the demand for beverage sugar as well as nonbeverage sugar in the United States.[19] Uri (1993) has shown that both the demand for beverage sugar and the demand for nonbeverage sugar destabilized around 1978. This corresponds to the period just after which HFCS-55 was introduced and when HFCS (both HFCS-42 and HFCS-55) was making large initial inroads into the sweetener market as a substitute for sugar (Vuilleumier, 1981, 1989). The demand for beverage sugar destabilized again in 1985. This corresponds to the first full year in which both the Coca-Cola Company and PepsiCo permitted 100 percent substitution of HFCS for sugar in their respective soft drink brands (Vuilleumier, 1989).

To account for the instability in the underlying demand relationships and its impact on the parameter estimates, a combination of dummy variables and the various explanatory variables was introduced into the specification for both the demand for beverage sugar and the demand for nonbeverage sugar. Preliminary analyses were undertaken to determine which of the variables to retain in the final specification. Those variables included are indicated in table 1.

The results of the stability test show that the impact of some variables on the quantity of beverage sugar and nonbeverage sugar changed

[15]There was no indication that higher orders of serial correlation were present based on an analysis of the residuals.

[16]Seemingly unrelated regression estimates (see Judge and others, 1985) were also obtained but there was no identifiable gain in estimate efficiency.

[17]The substitution of HFCS for sugar in soft drinks was a major factor in the development of the HFCS industry. HFCS-42 began to be substituted for sugar in 1974 by Coca-Cola in response to the increase in sugar prices. Other soft drink manufacturers soon followed suit. In 1978 Coca-Cola as well as the rest of the soft drink industry began shifting to HFCS-55. By November 1984, full replacement of refined sugar by HFCS-55 was approved by both Coca-Cola and Pepsi-Cola in their flagship brands (Butler, 1981; Vuilleumier, 1981, 1989).

The overall trend has seen sugar fall from accounting for slightly more than 67 percent of all caloric sweeteners consumed per capita in 1980 to around 46 percent in 1992 while HFCS has increased from accounting for less than 15 percent of total per capita caloric sweeteners consumption in 1980 to more than 35 percent in 1992 (Economic Research Service, March 1993). Moreover, in excess of 75 percent of HFCS sales in 1992 were associated with soft drinks while they were responsible for just 47 percent in 1980.

[18]Using the domestic price of sugar as the base, HFCS is priced at a discount to this price (Morris, 1980; Nordlund, 1977, and Vuilleumier, 1989).

[19]Stability is defined here in the statistical sense of the estimated coefficients on the explanatory variables remaining constant over time.

Table 1—Beverage sugar and nonbeverage sugar demand equation estimates (standard errors of the estimates in parentheses)

1. Beverage sugar demand

$$Q_{bt} = \underset{(0.6691)}{2.7968} + \underset{(0.0617)}{0.7987}\, Q_{b9t\text{-}1)} - \underset{(0.0152)}{0.0521}\, P_{ab(t)}$$

$$+ \underset{(0.0167)}{0.0347}\, P_{ot} + \underset{(0.9544)}{6.3588}\, ECON_t + \underset{(3.4365)}{22.0201}\, D78_t$$

$$- \underset{(3.5903)}{33.3881}\, D85_t - \underset{(0.8079)}{5.3371}\, ECON_{(78)T} + \underset{(0.7114)}{6.8224}\, ECON_{(85)t}$$

R^2 = 0.9976
Durbin h = 0.9786
S.E. = 0.3594

2. Nonbeverage sugar demand

$$Q_{nt} = \underset{(2.5576)}{7.8257} + \underset{(0.0864)}{0.8555}\, Q_{n(t-1)} - \underset{(0.0283)}{0.0882}\, P_{an(t)}$$

$$+ \underset{(0.0077)}{0.0514}\, P_{ot} + \underset{(0.0004)}{0.0145}\, ECON_t - \underset{(0.8182)}{3.1757}\, D78_t$$

$$+ \underset{(0.0010)}{0.0025}\, Q_{n78(t-1)}$$

R^2 = 0.9894
Durbin h = 1.0311
S.E. = 0.8402

Where Q_{bt} is the per capita quantity of beverage sugar demanded in period t, Q_{nt} is the per capita quantity of nonbeverage sugar demanded in period t, $P_{ab(t)}$ is the average price of beverage sugar in period t, $P_{an(t)}$ is the average price of nonbeverage sugar in period t, P_{ot} is the price of the sweetener substitute for sugar, $ECON_t$ in the beverage sugar demand equation is soft drink sales in period t and in the nonbeverage sugar demand equation it is disposable personal income, $D78_t$ is a qualitative variable equal to zero prior to 1978 and equal to 1 for 1978 and after, $D85_t$ is a qualitative variable equal to zero prior to 1985 and equal to 1 for 1985 and after, $ECON_{(78)t}$ is equal to zero prior to 1978 and is equal to soft drink sales in period t for 1978 and later, $ECON_{(85)t}$ is equal to zero prior to 1985 and is equal to soft drink sales in period t for 1985 and after, and $Q_{n78(t-1)}$ is equal to zero prior to 1978 and equal the quantity of nonbeverage sugar demanded in the previous period for 1978 through 1991. R^2 is the coefficient of determination. Durbin h is the Durbin h statistic used in testing for the presence of first order serial correlation, and S.E. is the standard error of the regression.

over the period 1960 through 1992. The effects of other variables, however, remained constant throughout the period. This does not mean that they had no affect on the quantity demanded, but that the magnitude of the effect did not vary over the sample period.

Finally, the structural instability in the demand for beverage sugar and the demand for nonbeverage sugar did not lead to erroneous results as far as the tests of the functional specification are concerned. The Davidson-MacKinnon statistical tests addressing both the selection of the adjustment specification and the linear specification were performed using the revised models taking into account the structural instability in both the beverage sugar demand and the nonbeverage sugar demand equations. In both instances, the previous test results were not changed.

The actual estimates of the beverage sugar and nonbeverage sugar demand equations that give rise to the structurally stable relationships are reported in table 1. The values in parentheses below the coefficient estimates are the standard errors of the estimates. The signs on the estimated coefficients are consistent with *a priori* expectations. Thus, for example, the demand for beverage sugar is inversely related to the price of sugar and directly related to the quantity of sugar demanded in the previous period, the price of sugar substitutes, and soft drink sales. The demand for nonbeverage sugar, on the other hand, is inversely related to the price of sugar and directly related to the price of sugar substitutes and disposable personal income.

With regard to the stability issue, the demand for beverage sugar destabilized in two ways. First, in both 1978 and 1985, the demand curve shifted as indicated by statistically significant (at the 5 percent level) coefficient estimates on the terms D78 and D85. Second, after 1978, the demand for beverage sugar became much less responsive to soft drink sales. In fact, the demand for beverage sugar is unresponsive to changes in soft drink

sales.[20] This responsiveness, however, increased to approximately its original level subsequent to 1985. Nonbeverage sugar demand also destabilized in two ways. First, in 1978, the demand curve shifted as indicated by the statistically significant (at the 5 percent level) coefficient estimate on the term D78. Second, the habit formation process changed such that consumers subsequently adjusted their consumption of sugar relatively more rapidly to changes in the price of sugar, the price of sugar substitutes and disposable personal income than they did prior to 1978, although this change was fairly modest.

Beyond these descriptive results, is there anything more definitive that can be concluded? Knowledge of the quantitative magnitudes of the responsiveness of consumers to changes in the various explanatory factors will help in answering this question. These magnitudes will be presented here as long-run elasticities and will be based on the estimated coefficients and the average values of both the dependent variable and the explanatory variables. Assuming the adjustment process given in relationship 2, the long run elasticity of a specific variable will equal (1/(1-a)) times the short run elasticity. The short run elasticity can be computed as the estimated coefficient on the variable under consideration times the average value of that variable divided by the average (computed based on a time period coincident with that of the variable of interest) of the quantity of beverage sugar (nonbeverage sugar) demanded.

Table 2 presents selected long-run elasticities for beverage sugar and nonbeverage sugar. Standard errors of these elasticity estimates are given in parentheses. They are computed following the suggestion of Horowitz (1981). The results are interesting from several points of view. First, the introduction of HFCS resulted in the demand for both beverage sugar and nonbeverage sugar becoming more price responsive (that is, the absolute value of the own price elasticity increased).[21] In both instances, the price responsiveness more than doubled between the first period (1960 through 1977) and the third period (1985 through 1992). In the case of beverage sugar, the cross price elasticity increased nearly fourfold between the first and third periods. For nonbeverage sugar, on the other hand, the cross price elasticity remains relatively small, though statistically significant at the 5 percent level. This is consistent with the argument that other sweeteners, for a variety of reasons, are not good substitutes for sucrose. The responsiveness of beverage sugar demand to soft drink sales is relatively large as would be expected with the relevant elasticity approaching one for both the first and third periods. During the second period (1978 through 1984), the soft drink sales elasticity decreases to zero partially in response to the introduction of HFCS-55.[22] By 1985, the adjustments to this new sugar substitute seem to have run their course with the soft drink sales elasticity returning approximately to the level it was at during the 1960-1977 period. The income elasticity for nonbeverage sugar is relatively small and a test of the null hypothesis that the income elasticity is constant across all three periods is accepted. Thus, there is a small but positive effect of changes in disposable income on nonbeverage sugar demand and this effect has remained roughly constant for the past three decades.

Table 2—Long run elasticities (standard errors of the estimates in parentheses)

Period(1)	Own price elasticity	Cross price elasticity	Other(2) elasticity
I. Beverage sugar			
(a) Period 1	–0.47 (0.20)	0.21 (0.09)	0.86 (0.32)
(b) Period 2	–0.86 (0.35)	0.27 (0.11)	0.21 (0.07)
(c) Period 3	–1.02 (0.41)	0.96 (0.34)	0.97 (0.39)
II. Nonbeverage sugar			
(a) Period 1	–0.19 (0.07)	0.07 (0.03)	0.17 (0.07)
(b) Period 2	–0.49 (0.19)	0.10 (0.04)	0.21 (0.09)
(c) Period 3	–0.50 (0.19)	0.12 (0.05)	0.23 (0.11)

(1) Period 1 corresponds to 1960 through 1977, Period 2 corresponds to 1978 through 1984, and Period 3 corresponds to 1984 through 1991.

(2) For beverage sugar, the other elasticity is for soft drink sales while for nonbeverage sugar, the other elasticity is for disposable personal income.

[20]That is, when the coefficient estimates on the two soft drink sales variables $ECON_t$ and $ECON_{(78)t}$ are considered in conjunction with their standard errors, it is not possible to reject the null hypothesis that their sum is zero. There is *a priori* no reason to expect this.

[21]Note that some of the variability in these elasticities is an artifact of the way in which they were computed. They are based on arithmetic averages of the respective variables over different time periods. However, the average values together with the reported standard errors and knowledge of the sample sizes will permit the reader to check that in fact the elasticities did (or did not) change in the manner suggested.

[22]It is not clear how reliable this elasticity estimate is since there was a relatively modest change in soft drink sales over this period but a substantial market penetration by HFCS-55. This would tend to obfuscate the impact of changes in soft drink sales on the demand for beverage sugar.

Next, it is useful to compare the results reported here with the estimates of others for the United States. First, note that few other studies have endeavored to disaggregate sugar demand into its beverage and nonbeverage components. Given the decline in beverage sugar consumption, especially in response to the introduction of HFCS, it is important to disaggregate. Secondly, no previous studies have focused on the structural stability issue. As can been seen from the foregoing analysis, this is an oversight that has significant ramifications with regard to estimating the response of both beverage and nonbeverage sugar demand to changes in the price of sugar, the price of sugar substitutes, soft drink sales, and disposable personal income.

One of the earliest studies of the demand for sugar was by Hayenga (1967). Using time series data covering 1949 through 1963 together with a linear specification, he finds an average price elasticity of demand for beverage sugar of –0.14 and an average elasticity for baking, canning, confection, and dairy products of –0.32. No soft drink sales or disposable personal income variables were included in his specifications. It is interesting to note that his estimates suggest that beverage sugar demand is less than one half as responsive to price changes as is nonbeverage sugar demand while the results obtained in this study suggest just the opposite.

Lamm (1982) estimates the demand for sugar as part of a system of dynamic demand functions. Only a short-run price elasticity is reported for total sugar consumption. This value is estimated to be –0.06 based on annual data covering 1946 to 1978. This is substantially smaller than the value of the short run elasticities obtained in this study. Given the nature of Lamm's study, it is difficult to determine why the difference is so great.

Other studies addressing the demand for sugar typically deal with the issue in a secondary role. That is, estimation of price and income elasticities were not the factor motivating the respective studies but rather are done in support of some other activity. As a consequence of this, there is typically scant discussion of the elements leading to an adopted demand specification. Nevertheless, it is useful to report some of these estimates for comparison purposes. Lopez (1989) estimates a long-run price elasticity of –0.59 for all sugar and an income elasticity of 0.49 based on data covering 1955-1985. Lopez and Sepulveda (1985) estimate an own price elasticity of –0.15 while King and George (1971) estimate an own price elasticity of –0.24. Finally, Leu and others (1987), using annual data covering 1961 through 1983, estimate a long-run elasticity of –0.32. This specification is unique among sugar demand studies in that it includes as explanatory variables in a linear specification not only the price of sugar in the current period but also the price in the previous period. A test of the specification used in the current study, as noted previously, does not support such a distributed lag.[23]

Measurement Error

Overview

There is one lingering problem that was alluded to previously. The coefficient estimates reported here are based on the assumptions that the model used has been properly specified, that an appropriate estimation technique has been employed, and that the data used are accurate. Is there reason to believe that one or more of these assumptions is invalid? With regard to the specification issue, considerable effort through a variety of statistical tests was expended to minimize the likelihood that the model was misspecified. Concerning the estimation technique, both ordinary least squares and the seemingly unrelated regression technique were used in preliminary analyses and the estimates obtained are consistent with one another. The accuracy of the data is another issue. In particular, measurement of the price of substitute sweeteners for sugar is problematic. Recall how this variable was measured. The composite price of substitute sweeteners for sugar was computed as a weighted average of the prices of glucose corn syrup, dextrose, and high fructose corn syrup (both 42 percent and 55 percent). There are several problems with this measure. First, some components of this price series are discontinuous. Namely, HFCS did not exist prior to 1969 whereas

[23]One final empirical test was performed. This involved testing for data outliers using the regression diagnostic techniques of Belsley, Kuh, and Welsch. These diagnostic techniques look at whether the coefficient estimates are inordinately influenced by a subset of the data. This is relevant since there are a few time periods where substantial changes occur in the data. For example, a look at Figure 1 shows that the quantity of both beverage sugar and nonbeverage sugar demanded fell precipitously in 1975. This fall was the result of a jump in the price of granulated sugar from 15 cents per pound at the beginning of 1974 to 72 cents per pound at the beginning of 1975. This price increase generated by a number of factors including the increased cost of producing refined sugar, difficulties in processing and transporting sugar associated with the 1973-1974 energy crisis, world wide inflation, currency devaluation, and uncertainties about United States sugar policy. A fairly complete discussion of this is contained in *Confectionery Production* (May 1975) and Bohall and others (1977). In the context of the current discussion, then, did the year 1975 have a disproportionate impact on the reported (price) coefficient estimates? There are no observations for either of the equations that are judged to be beyond the cutoff points.

the data series extends back to 1960. This means that for the series on the composite price of the substitute sweeteners for sugar, its underlying structure changes in 1970 because four price series rather than two contribute to its makeup. Second, inclusion of the price of glucose corn syrup and dextrose as components of the series might be questioned because they are not good substitutes for sugar in many uses and the relative importance of the uses in these instances changed over time. Finally, for the reasons previously indicated, no provision is made in the composite price of the substitute sweeteners measure for noncaloric sweeteners and they are a substitute for sugar in some uses (Moore and Buzzanell, 1991).

Based on these considerations, while the price variable used to reflect any substitution effects of other sweeteners for sugar is the best that could be constructed, it is still a relatively poor measure to rely upon because of the measurement error it contains. Assuming this measurement error is random,[24] it will impact the estimated value of the coefficient on the substitute sweeteners price variable as well affect the coefficient estimates on all of the other explanatory variables. To understand this, a brief digression is in order. Theoretical Considerations

The classical regression model is defined as

$$y_t = \Sigma_i \beta_i x_{it} + \gamma z_t + e_t \qquad (6)$$

for $i = 1, 2, \ldots, k$, $t = 1, 2, \ldots, n$ and where y_t is the dependent variable with zero mean and constant variance containing no measurement error, the x_{it} are independent variables with zero means and constant variances and they are observed with no measurement error, and z_t is a true variable that should properly be included in an empirical relationship but for which accurate observations are not available. It is further assumed that e_t, the random error term, has a zero mean and a constant variance and is uncorrelated with y_t and x_{it}. Finally, it is assumed that e_t has a constant variance, σ_{ee}.

Random measurement error for an independent variable exists when observations are not available for z_t but they are available for Z_t where the relationship between z_t and Z_t is given by

$$Z_t = z_t + u_t \qquad (7)$$

where u_t has a zero mean and it is uncorrelated with e_t, y_t and x_{it}. Moreover, it is assumed that u_t has a constant variance, σ_{uu}.

There are two diagnostics that are useful in evaluating the effects of random measurement error on the estimates. These are the regression coefficient bounds and the bias correction factor. Regression coefficient bounds prove to be useful because they indicate the impact on the estimated regression coefficients of not only the random component in y_t but the random component of the explanatory variable that contains the measurement error as well. The bias correction factor is useful because it will indicate the extent of the difference between the true population parameter and the estimated value of the parameter.

Regression coefficient bounds are computed in a fairly straightforward fashion and this computation process is well known (Fuller, 1987; Herbert, 1988, and 1989; and Maddala, 1988). What one finds is that when random measurement error is present, the estimated regression coefficient on the variable possessing the measurement error is the lower bound estimate of the true population parameter (if the true population parameter is positive).[25] The upper bound estimate (or lower bound estimate if the true population parameter is negative) is given by one divided by the coefficient estimate on the reverse regression. The reverse regression results when the variable containing the measurement error is regressed on the dependent variable and the set of other explanatory variables (that is, those not possessing measurement error). The degree of the underestimation of the true population parameter depends on σ_{uu}/σ_{zz}. Also, the better the data fit the estimated relationship, the closer are the bounds.

Following Herbert and Dinh (1989), the expression for bias, BIAS, is given as

$$\text{BIAS} = \frac{\gamma\ (\Sigma_{xx})^{-1}\ \sigma_{Zx}}{1 + \Omega} \qquad (8)$$

where $x = (x_1, x_2, \ldots, x_k)$, $\Omega = (\sigma_{zz}\ (1 - (p_{Zx})^2))/(\sigma_{uu})$ and p_{Zx} is the multiple correlation coefficient between the true Z and the other correctly measured (that is, possessing no measurement error) explanatory variables.

The variance-covariance matrix of the x_t and Z_t is written as

[24]There is no reason to assume otherwise. That is, there is no basis for assuming that there is some systematic error in the variable as it is measured.

[25]It represents the upper bound if the true population parameter is negative.

$$\Sigma_{xZ} = \begin{bmatrix} \Sigma_{xx} & \sigma_{Zx} \\ (\sigma_{Zx})' & \sigma_{ZZ} \end{bmatrix} . \qquad (9)$$

It is assumed that σ_{Zx} is not equal to zero.

Given these diagnostics, in what follows both the regression coefficient bounds and the bias correction factor will be computed for the previously estimated demand relationships for beverage sugar and nonbeverage sugar.

Regression Coefficient Bounds

Consider first the regression coefficient bounds question. Since the population parameter is (theoretically) positive, the values reported in table 1 for beverage and nonbeverage sugar represent the lower bound estimates of the impact of a change in the price of the substitute sweeteners for sugar. The upper bounds are computed from the reverse regression. The reverse regression estimation results are presented in table 3 (with the standard errors of the estimates in parentheses and all of the variables as previously defined). Note that the results of the stability test performed on the reverse regressions did not indicate that there was any structural shift in the relationships estimated. Consequently, unlike the situation when the quantity of beverage sugar and nonbeverage sugar were the dependent variable, no additional variables had to be introduced to account for variation in the coefficients on the explanatory variables at different time periods.

From these results, for beverage sugar the lower bound estimate is computed as 1.18 while for nonbeverage sugar it is computed as 1.12. Hence, the coefficient bounds for the population parameter C_1, for beverage sugar are given as $0.03 < C_1 < 1.18$ while for nonbeverage sugar they are given as $0.05 < C_1 < 1.12$.

One procedure recommended for obtaining a single estimate to use in assessing the impact of the variable possessing measurement error on the dependent variable is to compute the geometric average. For the current problem, the geometric average for beverage sugar is 0.19 and for nonbeverage sugar, it is 0.24 (Frisch, 1934; Samuelson, 1942).

These results suggest that, due to the presence of random measurement error, there is considerable uncertainty associated with consumers' response to changes in the price of substitute sweeteners for sugar in the short run. Thus, using the mean values of the prices and quantities over the period 1985 to 1992, a 1 percent increase (decrease) in the

Table 3—Beverage sugar and nonbeverage sugar demand reverse regression equation estimates (standard errors of the estimates in parentheses)

1. Beverage sugar demand

$$P_{ot} = \underset{(3.5318)}{29.523} + \underset{(0.1903)}{0.2081}\, Q_{b(t-1)} + \underset{(0.1109)}{0.2630}\, P_{ab(t)} + \underset{(0.2451)}{0.5623}\, Q_{bt} + \underset{(0.0013)}{0.0045}\, ECON_t$$

$R^2 = 0.9010$
Durbin h $= 0.9623$
S.E. $= 0.7317$

2. Nonbeverage sugar demand

$$P_{ot} = \underset{(12.330)}{28.603} + \underset{(0.1982)}{0.2310}\, Q_{n(t-1)} + \underset{(0.1275)}{0.2618}\, P_{an(t)} + \underset{(0.3102)}{0.5311}\, Q_{nt} + \underset{(0.0059)}{0.0054}\, ECON_t$$

$R^2 = 0.9343$
Durbin h $= 1.0520$
S.E. $= 0.0899$

Where Q_{bt} is the per capita quantity of beverage sugar demand in period t, Q_{nt} is the per capita quantity of nonbeverage sugar demanded in period t, $P_{ab(t)}$ is the average price of beverage sugar in period t, $P_{an(t)}$ is the average price of nonbeverage sugar in period t, P_{ot} is the price of the sweetener substitute for sugar, $ECON_t$ in the beverage sugar demand equation is soft drink sales in period t and in the nonbeverage sugar demand equation it is disposable personal income, $D78_t$ is a qualitative variable equal to zero prior to 1978 and equal to 1 for 1978 and after, $D85_t$ is a qualitative variable equal to zero prior to 1985 and equal to 1 for 1985 and after, $ECON_{(78)t}$ is equal to zero prior to 1978 and is equal to soft drink sales in period t for 1978 and later, $ECON_{85(t)}$ is equal to zero prior to 1985 and is equal to soft drink sales in period t for 1985 and after, and $Q_{n78(t-1)}$ is equal to zero prior to 1978 and equal the quantity of nonbeverage sugar demanded in the previous period for 1978 through 1992. R^2 is the coefficient of determination, Durbin h is the Durbin h statistic used in testing for the presence of first order serial correlation, and S.E. is the standard error of the regression.

aggregate price of substitute sweeteners for sugar will result in between a 0.19 and 0.92 percent increase (decrease) in the quantity of beverage sugar demanded with a geometric average of 0.41 and between a 0.02 and 0.77 percent increase (decrease) in the quantity of nonbeverage sugar demanded with a geometric average of 0.12. These are wide ranges and make inferences about consumers' behavior in the face of changes in the price of the substitute sweeteners for sugar very tenuous. The regression coefficient bounds for the long run price elasticities are comparably large. For beverage sugar based on data covering 1985-1992, a 1 percent increase (decrease) in the price of substitute sweeteners for sugar will result in between a 0.93 and 4.49 percent increase (decrease) in the quantity of beverage sugar demanded with a geometric average of 2.04 and between a 0.13 and 5.02 percent increase (decrease) in the quantity of nonbeverage sugar demanded with a geometric average of 0.81.

Bias Correction Factor

What does the bias correction factor indicate? To expedite the discussion, details for just one of the explanatory variables, the price of sugar, P_{at}, will be provided while results for soft drink sales (for beverage sugar) and disposable personal income (for nonbeverage sugar) will simply be indicated. Consider the bias associated with the coefficient estimate on the price of sugar. From the data used in the estimation of relationship 5 and from the estimation results, the following calculated values for the period 1985 through 1992 were obtained:

Beverage Sugar Demand

$(\Sigma_{xx})^{-1}\ \sigma_{Zx} = 0.5135$, $\sigma_{ZZ} = 28.6761$, $\sigma_{Zx} = 38.8260$, $(p_{Zx})^2 = 0.5409$

Nonbeverage Sugar Demand

$(\Sigma_{xx})^{-1}\ \sigma_{Zx} = 0.6021$, $\sigma_{ZZ} = 28.6761$, $\sigma_{Zx} = 19.8560$, $(p_{Zx})^2 = 0.5409$.

The sole remaining value to be determined is σ_{uu}. Fuller (1987), for the situation when random measurement error is present, gives the expression for σ_{uu} as,

$$\sigma_{uu} = \sigma_{ZZ} - (\sigma_{Zy})^2\ (\sigma_{yy} - \sigma_{ee})^{-1} \tag{10}$$

where σ_{yy} is the variance of the dependent variable and the other terms are as previously defined.

A maximum value for σ_{uu} is obtained by setting $\sigma_{ee} = 0$. This assumption will be employed here. With this expression (that is, equation 10), the final pieces of information needed to compute the bias are σ_{yy} and σ_{Zy}. In the current examples, for beverage sugar, $\sigma_{yy} = 15.2827$ and $\sigma_{Zy} = 11.2862$ and for nonbeverage sugar, $\sigma_{yy} = 19.6272$ and $\sigma_{Zy} = 14.2714$. Using relationship 10 and the computed values of the variances and covariances, the computed value for beverage sugar of $\sigma_{uu} = 20.3413$ and for nonbeverage sugar, it equals 18.2990.

Given these values, the bias associated with the coefficient estimate on the price of sugar is 0.0107 for beverage sugar and 0.0103 for nonbeverage sugar. For beverage sugar, this is equal to about 20.9 percent of the estimated coefficient for the price of sugar variable and indicates the extent of the over-estimation of the response of the quantity of beverage sugar demanded to a change in the price of sugar.[26] For nonbeverage sugar, the over-estimation is approximately 11.6 percent. Thus, the measurement error associated with the sugar sweetener substitutes price variable yields an estimate of the response of variation in the quantity demanded of beverage and nonbeverage sugar demanded to changes in the price of sugar that is too large.

Analogous computations can be performed for the soft drink sales variable (for beverage sugar) and disposable personal income variable (for non-beverage sugar). Omitting the computation details, the bias in the coefficient on the soft drink sales variable is 1.6708 or 21.3 percent of the estimate while the bias in the coefficient estimate on the disposable personal income variable is .0024 or 16.8 percent. Thus, in both instances measurement error in the substitute sweeteners price variable results in an over-estimation of the response of the quantity of sugar demanded to changes in soft drink sales and disposable personal income.

Conclusion

This paper began by discussing some of the problems frequently encountered in obtaining estimates of the elasticity of demand. To these problems was added that associated with inaccuracy in the measurement of one of the independent variables that impact the quantity demanded. Two diagnostics—the regression coefficient bounds and the bias correction factor—were introduced to assess the affect that such measurement error has on the estimated coefficients of demand relationships.

In considering the demand for beverage sugar and nonbeverage sugar in the United States, the price data for the substitute sweeteners for sugar contains measurement error. The regression coefficient bounds diagnostic was used to indicate a range in which the true price responsiveness of consumers to changes in the price of sugar substitutes lies. The results suggest that each 1 percent increase (decrease) in the price of sugar substitutes will result in between a 0.19 and 0.92 percent increase (decrease) in the quantity of beverage sugar demanded and between a 0.02 and 0.77 percent increase (decrease) in the quantity of nonbeverage sugar demanded in the short run. In the long run, each 1 percent increase (decrease) in the price of sugar substitutes will result in between a 0.93 and 4.49 percent increase (decrease) in the quantity of beverage sugar demanded and between a 0.13 and 5.02 percent increase (decrease) in the quantity of nonbeverage sugar demanded. The bias correction factor was computed to evaluate the magnitude of the over-estimation of the responsiveness of the quantity of

[26]Given the way the elasticity is computed in table 2, this is the magnitude of the overestimation of the beverage sugar price elasticity estimate as well. This also holds for non-beverage sugar.

beverage sugar and nonbeverage sugar demanded to a change in the price of sugar. For beverage sugar, the over-estimation associated with the price of sugar variable was 20.9 percent while for nonbeverage sugar it was 11.6 percent. With regard to soft drink sales, the bias in the coefficient was 21.3 percent of the estimate while the bias in the coefficient estimate on the disposable personal income variable was 16.8 percent.

These results suggest that, in the presence of measurement error in the data for the price of the sweetener substitute, any conclusions or policy recommendations based on the estimated sugar demand relationships must be qualified. Consider the following. Policy analyses using estimates of the demand for sugar must be cognizant of the fact that the period being studied must use the appropriate elasticity estimate. Thus, for example, the U.S. General Accounting Office (GAO) estimates that the sugar program administered by the USDA costs U.S. consumers approximately $1.4 billion annually. A critical assumption in this analysis is a sugar price elasticity of –0.05 and is based on the historical period covering 1970-1987. This value is used in conjunction with a variety of supply elasticities ranging between 0.1 and 2.0 to get the reported result. From the results of the analysis in this paper, the appropriate price elasticity would be based on the period 1984-1992 which indicates a larger price responsiveness on the part of sugar consumers. The estimated annual impact of the sugar program would be less. Additionally, the uncertainty in the estimated price responsiveness of consumers associated with the measurement error in the price data for the substitute sweeteners for sugar must be reflected in the analysis.

An alternative use of demand elasticities is for forecasting purposes. For example, under the sugar program as configured in the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-624), provision is made for standby domestic marketing allotments. USDA annually estimates the domestic production and quantity demanded for sugar and the supply quantity needed to keep domestic prices at a level that prevents producers from forfeiting sugar. USDA, in consultation with the Sugar Working Group, then determines the quantity of sugar to import. The Sugar Working Group is composed of representatives of various government agencies possessing an interest in the sugar program. The 1990 law requires that the quota be at least 1.25 billion short tons to ensure that sugar cane refiners continue to have access to foreign raw sugar. The quota also enables the federal government to meet foreign policy objectives. The U.S. Trade Representative allocates the quota to individual countries who can then export their quota to the United States.

If the import quota is met and if the price of sugar falls below the forfeiture level, domestic marketing allotments are to be used to support prices. These allotments restrict the quantity of domestically produced sugar and crystallized high fructose corn syrup that each manufacturer can sell. To administer marketing allotments, marketing rights based on historical production, ability to market sugar, and production capacity of sugar cane millers and sugar beet processors would be used. Of critical importance in predicting the impact of marketing allotments is knowledge of the sugar price elasticity and the cross price elasticity of substitute sweeteners. Recognition of what these elasticities are, the uncertainty of their measurement, and how they have changed over the historical period must be factored into the assessment of the effect of marketing allotments. For example, an assumed elasticity that is too small will yield marketing allotments that are too large, thereby reducing the net farm income of domestic sugar producers.

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Price Elasticities Implied by Homogeneous Production Functions

J. Michael Price

Abstract. *If a production process is characterized by a homogeneous production function, the conditions required for profit maximization imply that the elasticity of demand for each input must be elastic with respect to output price. This restriction limits the usefulness of these functions in empirical analysis.*

Keywords. *Homogeneous production functions, Cobb-Douglas production functions, elasticity of input demand, elasticity of supply.*

Chand and Kaul (1986)[1] have demonstrated that using the Cobb-Douglas profit function to characterize a production process imposes a number of restrictions on the price elasticities of input demand. However, since every Cobb-Douglas profit function corresponds to a Cobb-Douglas production function, their results are also applicable to the case where the production process is characterized by a Cobb-Douglas production function. The purpose of this note is to show that one of the more important restrictions derived by Chand and Kaul also applies to the more general case of a homogeneous production function.

Profit Maximization

Assume that the production process requires, at most, n inputs to produce a single output. Let f denote the corresponding production function. Then

$$y = f(x),$$

where x is an n-dimensional vector of inputs with $x \geqslant 0$, and $y \geqslant 0$ is output.[2] Assume that f is strictly quasi-concave and twice continuously differentiable with positive first order derivatives.

The profit function is defined as

$$\pi\ (p,\ w,\ x) = p \cdot y - w \cdot x,$$

where w represents the n-dimensional vector of positive input prices and p denotes the positive output price. If the producer is a price-taker in all markets, profit maximization involves determining some value of $x^* \geqslant 0$, such that

$$\pi\ (p,\ w,\ x^*) \geqslant \pi\ (p,\ w,\ x)$$

for all $x \geqslant 0$.

This constrained optimization problem may be conveniently broken into two parts (Takayama. 1985, p. 142). First, minimize the cost function $w \cdot x$ subject to the constraints that $f(x) \geqslant y$ and $x \geqslant 0$. Because f is continuous, the solution to this cost minimization problem gives rise to a minimum cost function, c, defined for all values of w and y, with

$$c\ (w,\ y) \leqslant w \cdot x$$

for all x satisfying the constraints (Diewert. 1982, pp. 537–538). Shephard (1981, pp. 43-45) has shown that if the production function is homothetic and satisfies the conditions above, then there exist functions, h and g, such that

$$c\ (w,\ y) = h\ (w) \cdot g\ (y) \tag{1}$$

and

$$x_i\ (w,\ y) = [\partial h\ (w)/\partial w_i] \cdot g\ (y)\ (i = 1,\ 2,\ \ldots,\ n), \tag{2}$$

where $x_i\ (w, y)$ denotes the derived demand for the i^{th} input based on the cost minimization problem. The solution to the profit maximization problem is then given by determining that value of $y \geqslant 0$ which maximizes

$$p \cdot y - c\ (w,\ y).$$

Assume now that f is also positively homogeneous of degree k with respect to x. As is well known. there does not exist a unique solution to the profit maximization problem, if the production function exhibits either increasing or constant returns to scale ($k \geqslant 1$). Therefore, restricting the production function to having decreasing returns to scale ($k < 1$) is a necessary condition for obtaining a unique

Price is a senior economist with the Agriculture and Trade Analysis Division, ERS.

[1]Sources are listed in the References section at the end of this article.

[2]For any vector, z, the notation $z \geqslant 0$ will be used to indicate that each component of the vector is non-negative.

input level, x^*, satisfying the profit maximization conditions.[3]

Because the production function is homogeneous, f is also homothetic. Therefore, Shephard's results are applicable. In addition, the function g in equation 1 is given by $g(y) = y^{1/k}$ (Shephard, 1981, p. 43). Thus, the profit maximization problem reduces to finding $y \geqslant 0$ which maximizes the expression

$$p \cdot y - h(w) \cdot y^{1/k}.$$

The first order conditions for a maximum imply that

$$p - (1/k) \cdot h(w) \cdot y^{(1-k)/k} = 0,$$

which, after rearranging terms, yields

$$y(w, p) = [p \cdot k \cdot h(w)^{-1}]^{k/(1-k)}, \tag{3}$$

where $y(w, p)$ denotes the output level which maximizes profit for each level of w and p. Furthermore, substituting equation 3 into equation 2 yields the input demand function corresponding to the profit maximization problem

$$x_i\,(w, y(w, p)) = [\partial h(w)/\partial w_i] \cdot [p \cdot k \cdot h(w)^{-1}]^{1/(1-k)}. \tag{4}$$

Restrictions on the Price Elasticities

Equation 4 implies that the elasticity of the derived demand for input i with respect to output price is $(1 - k)^{-1}$ for i = 1, 2, ..., n. Because profit maximization requires that k be less than one, this implies that $(1 - k)^{-1} > 1$. Hence, the conditions required for profit maximization imply that the elasticity of demand for each input with respect to output price is elastic and that this elasticity is identical for all inputs. This restriction is identical to "characteristic five" given by Chand and Kaul (1986). However, the result is now seen to pertain to a much wider class of production functions.

Examination of equation 3 yields a result that augments the work of Chand and Kaul (1986). This equation implies that the elasticity of supply with respect to output price is $k \cdot (1 - k)^{-1}$. Thus, the elasticity of supply with respect to output price will be inelastic only if $k < 1/2$. This condition may provide a useful check for selecting production functions to characterize a particular industry.

Conclusions

The restrictions derived above should be considered before selecting a homogeneous production function to characterize a particular production process. If prior knowledge or empirical evidence suggests that the restrictions implied by the profit maximizing conditions are apt to be violated for a particular industry, alternative methods should be used to model the production process.

The preceding results demonstrate that the restrictions needed to ensure profit maximization are inconsistent with inelastic input demand functions. Therefore, if there is reason to suspect that input demand is inelastic with respect to changes in output price, homogeneous production functions should not be used to model the production process.[4] Moreover, this restriction may be especially pertinent for agricultural commodities. Estimates by Ball (1988), for example, indicate that many of the inputs used in agricultural production may be inelastic with respect to output price.

The restrictions implied by profit maximization on the elasticity of supply with respect to output price are less serious. If supply is believed to be inelastic with respect to output price, only those functions which are homogeneous of degree less than one half are relevant. This result only limits the class of homogeneous functions that are appropriate in certain applications. It does not preclude their use entirely.

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[3]If the production function is employed to model aggregate production for a commodity, these remarks are not strictly true. Even if the production function for the market exhibits constant returns to scale, price and quantity will be uniquely determined by the interaction of aggregate supply and demand (Samuelson, 1974, pp. 78-89). Varian (1984, p. 27), however, observes that employing the assumption of decreasing returns is reasonable if we restrict our attention to the short-run. Moreover, Chand and Kaul (1986) implicitly employ this assumption in their work.

[4]It is noted in passing that, in addition to the Cobb-Douglas function, the Arrow-Chenery-Minhas-Solow constant elasticity of substitution function is also homogeneous.

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A Detailed, Useful Look at Vegetable Markets

Vegetable Markets in the Western Hemisphere. *Edited by Rigoberto Lopez and Leo C. Polopolus. Ames: Iowa State University Press, 1992, 266 pages, $32.95.*

Reviewed by A. Desmond O'Rourke

This book is an excellent exploration of the major forces shaping vegetable markets in the western hemisphere and, to some extent, around the world. The book is the outcome of a conference on the same theme held at Rutgers University in 1988. The conference organizers did an excellent job of choosing speakers who could address a wide variety of issues and who could also approach topics from differing perspectives.

The book's first section explores vegetable demand changes over time (Hamm) and across socio-demographic groups (McCracken). In Section II, Pierson and Allen demonstrate how the distribution system is adjusting to changes in demand, technology, and trade. Polopolus documents the surprising level of U.S. government intervention in vegetable markets. Schwedel provides an insightful discussion of Mexican government intervention.

The third and fourth sections of the book focus on various aspects of trade in vegetables. Cook examines the increasing integration of the California, Arizona, and Mexican vegetable industries. The next two papers contrast empirical analysis of trade in vegetables (Sparks) with conceptual analysis (Lopez and Pagoulatous). Vertrees and Meyer demonstrate how the Uruguay Round negotiations may impact vegetable trade. A further two papers examine the Caribbean Basin Initiative (CBI) from U.S. (Seale) and the Caribbean (Guardia) perspectives. Both agree that the CBI in vegetables can have only modest economic development impact. A final paper by Martin and Thompson examines the complex linkages between vegetable trade and the labor markets in the United States and Mexico.

Both the main papers and the excellent responses to those papers provide often subtle but valuable insights into the key forces affecting vegetable markets. For example, it is difficult to relate improvements in nutritive intake of vegetables to increases in disappearance because of changes in how and where vegetables are consumed. Also, in discussions of free trade in vegetables, it is important to consider the general welfare benefits of increased trade as well as the industry impacts. A number of contributors comment on the decaying data system and the problems it poses for critical trade and policy analysis. Pierson and Allen document how the vegetable business is moving from a production/commodity-based system to one where market-oriented strategies will dominate. Also interesting is the role of the National Union of Vegetable Producers (UNPH), in cooperation with the Mexican Government, in controlling exports of fresh Mexican vegetables.

The papers on trade illustrate that trade involves not just commodity producers and sellers on either side of international borders but the political and social agendas of participating and third countries. For example, relocation of California vegetable operations to Mexico in response to less hospitable relations at home may eventually lead to Mexican-owned competing operations. Brader notes that meeting demands for pesticide inspection of imports would require an additional 5,000 inspectors and be "incredibly expensive." Lopez and Pagoulatos demonstrate that pesticide restrictions will lead to reduced trade and higher prices. Martin and Thompson illustrate both the unreliability of data on farm labor availability and the difficulty of predicting how changes in trade policy might affect internal or cross-border availability or price of farm labor, which in turn affects competitiveness of trade partners.

This book will be a valuable source of information and insights for policymakers, industry leaders, economic and market analysts and others interested in the health, environmental, labor, natural resource, or other aspects of vegetable production, consumption, and trade. Many of the chapters would be appropriate readings for graduate or undergraduate trade and marketing classes. Clearly, vegetables will remain an important element of the North American Free Trade Agreement (NAFTA), the CBI, and other hemispheric trade agreements.

The major weakness of the book is one that is out of the control of the authors. Because the contributions were derived from a 1988 conference and had access only to 1987 data, there is little or no coverage of the Canada-U.S. Trade Agreement, NAFTA, or major developments in the General Agreement on Tariffs and Trade (GATT). An updated compendium on many of the issues raised in the book would be invaluable. There is also a lack of coverage of the potential role of Argentina, Brazil, and Chile in Western Hemisphere vegetable markets, either as suppliers or as markets. However, these comments are not meant to detract from the usefulness of the comprehensive work.

The History of the Profession in the History of a Man—Karl Fox

Demand Analysis, Econometrics, and Policy Models: Selected Writings by Karl A. Fox. *Edited by S.R. Johnson, J.K. Sengupta, and E. Thorbecke. Ames: Iowa State University Press, 1992.*

Reviewed by Henry W. Kinnucan.

This 345-page hardcover, indexed volume is the first of a planned 2-book set on the writings and professional life of a man who was at the center, if not the leading edge, of major advances in quantitative policy analysis. The volume contains 16 selected writings covering roughly the first quarter-century of Fox's career (through 1969). As such, we get only a partial glimpse of the man's contributions and the book must be judged from that perspective. The book differs from similar works (for example, Houck and Abel's selected writings of F. V. Waugh) in that Fox himself provides retrospective commentary on each selection. This adds a nice personal and historical dimension to what might otherwise be a heavy academic tome.

Although the selections are divided into five parts (Demand Analysis for Farm and Food Products, Spatial Equilibrium Models, Studies of Interaction Between Agriculture and the Nonfarm Economy, Econometric Models and Policy for Stabilization and Growth, and the Theory of Economic Policy), a chronological order is maintained so that the reader gets a sense of Fox's intellectual growth as his career unfolds. The "scientific autobiography" and section introductions written by the editors create a well-rounded finished product.

The reader is immediately struck by the importance of the simultaneous equation problem in Fox's early career. Because the problem was to occupy him for nearly three decades and to permeate his writings, a short historical overview might be in order. Beginning in about the 1920's, a number of pioneering economists, most notably Henry Schultz of the University of Chicago, began applying regression procedures to the estimation of demand functions. The best available data at the time were those maintained by the U.S. Department of Agriculture.

Kinnucan is Professor in the Department of Agricultural Economics and Rural Sociology, Auburn University.

By the beginning of World War II, through the diligent efforts of a number of econometricians, Fox among them, a rather impressive set of results had been amassed on demand elasticities for the major food and fiber commodities. A euphoria of sorts was beginning to set in; it would only be a matter of time before a complete "econometric road map" of the agricultural sector could be made available for policy analysis. Then came Haavelmo's 1943 *Econometrica* article, "The Statistical Implications of a System of Simultaneous Equations." As Fox describes it (p. 38): "From 1944 to 1953, news about Haavelmo's approach, commonly referred to as the 'simultaneous equation approach,' or 'Cowles Commission Technique,' spread rapidly among econometricians by word of mouth, through journal articles, and finally through two Cowles Commission monographs published in 1950 and 1953. Econometricians who had done serious empirical work were not impressed, but the new approach became gospel among graduate students with strong mathematical backgrounds and with a predilection for teaching rather than research."

Not surprisingly, Fox was among—perhaps the leading spokesman for—those who were not impressed with Haavelmo's critique. But it would be a mistake to interpret this as a defensive reaction to protect his own work. (Fox at the time had recently completed extensive work in the estimation of price-dependent demand equations using ordinary least squares (OLS).) In vintage style, Fox advanced a carefully reasoned argument to show why not all economic relationships estimated by OLS suffer from simultaneous-equation bias. Arrow diagrams, a Fox trademark, were used to illustrate hypotheses about the direction of influences among variables and to demonstrate why and under what conditions supply, demand, and certain other relationships within a model could be estimated appropriately by least squares. (The diagrams were used to such effect that Thorbecke was later to comment (p. 252), "I remember how impressed I had been at Fox's arrow diagrams and his emphasis on causal chain models.... This was the reason why ... I painstakingly worked out the complete causal ordering among endogenous variables of the model used by the Dutch Central Planning Bureau.")

The battle lines were drawn. Despite the clarity and common sense of his early arguments, Fox found it necessary to revisit the issue in virtually

all of his econometric writings over the next 25 years. One particularly poignant observation appeared in his 1956 review of Klein and Goldberger's econometric model, when he states (p. 173), "Some younger economists have come to believe that a coefficient derived by [the limited-information maximum-likelihood method] is 'right,' while a coefficient derived by any other method is 'wrong.' Actually, the general theory that underlies the limited-information method often leads one to single-equation, least squares estimation as a special case." Fox then went on to show that the coefficients estimated in the Klein and Goldberger model were at least as sensitive to the sample period as to the estimating technique. (Adding just two observations to the 1929-50 estimation period caused as many differences in the coefficients as changing the estimation technique!)

Fox was convinced that relative to other problems such as measurement error and specification error (he was particularly impressed by a lemon demand study that included temperature as an explanatory variable), the simultaneous-equation problem was a red herring. The sensitivity to potential data errors led Fox in his early demand studies to use novel procedures to assess the reliability of the estimated parameters that are worth restudying even today. His meticulousness with data, one of his many admirable qualities as a scientist and researcher, is apparent in the following passage (p. 237): "... while I was estimating statistical demand functions for a wide range of agricultural commodities and food, I tried to arrive at judgment estimates of the level of *ex post* measurement error in the time series I was using. My procedure was to interview the persons responsible for estimating each of the published series on commodity prices and production." He had little time for "academic economists, who were mainly interested in 'testing' theories or techniques" and whose "ignorance or disregard of data limitations often vitiated [their] empirical work." Who would claim that this problem is any less severe today than when Fox expressed his views in the *International Encyclopedia of the Social Sciences* over 20 years ago?

The rectitude of Fox's position with respect to the simultaneous-equation "problem" is buttressed (if not vindicated) by Tomek's remarks some 30 years later to the American Agricultural Economics Association (p. 18): "In the 1950's ... simultaneity was seen as a relatively important problem, and errors in variables were barely mentioned. Now, it seems clear that biases related to specification error and errors in variables are often more important than those related to simultaneity." And I am sure that Fox would endorse, indeed applaud, Tomek's further comment (p. 18) that "The approbation given econometric methods by price analysts, however, sometimes limits progress in price analysis by shifting incentives away from improving models and data. For example, a paper applying a novel econometric procedure to mediocre data may be judged to be a more meritorious contribution than a paper applying a conventional econometric method to novel data or to an improved model." Other leading price analysts (see Gardner, p. 887) have expressed similar reservations. In short, Fox was right.

The second major theme of Fox's professional life during the early postwar years is his steadfast belief in the value of econometric models for policy evaluation and rational decisionmaking. Thorbecke describes how Fox at economic workshops at Iowa State University was fond of saying, "The alternative to a model is a muddle" (p. 251). This belief stemmed in good measure from Fox's keen awareness of the interrelatedness of different sectors of the economy. Planned decreases in defense spending after World War II, for example, could adversely affect the agricultural sector by reducing personal income and therefore the domestic demand for agricultural commodities. The ensuing reduction in farm income, in turn, would likely have a "back effect" on the nonfarm economy by reducing cash outlays for inputs, such as farm buildings and equipment. Fox foresaw that properly constructed econometric models could be of immense help to policymakers in understanding the nature, timing, and magnitude of proposed policy actions.

It helps to remember that Fox was articulating these views at a time when rigorous quantitative analysis of policy proposals was anything but routine. There was considerable skepticism that anything of value could come from econometric models, even among professional economists. In the early 1950's, the conventional wisdom, according to Fox, was that "all economic relationships should be dealt with on an intuitive level—that no tangible mechanism should intervene between the raw material (individual time series) and the finished product (policy recommendations)." The problem with this approach, Fox argued, was that it "... requires an act of faith on the part of both the giver and the receiver of economic advice." At this point he asserts his belief in clear and forceful terms, "... the policy implications of a host of raw time series can be made clear if they are organized into an econometric model—a system of equations which translates the concept of interrelatedness into an explicit, quantitative, reproducible form" (p. 171).

A curious aspect of Fox's work is that it failed to incorporate the downside of farm policy. Surely with his active interaction with macroeconomic modelers of the time (Klein, Goldberger, Tinbergen, among others) and his sensitivity to sector interrelatedness, Fox must have known that the tax increases (or deficit financing) needed to fund farm policies could have potentially damaging "back effects" on the general economy. And his keen economic intuition should have tipped him off to the long-run consequences of price-support programs in terms of inflated asset values and erosive cropping practices. Yet we never see mention of second- and third-order effects of this type. Why the blind spot? The tenor of the times? Or is it a product of Fox's self-described position as a "policy liberal"?

For those who like to study a subject area (as I do) through the prism of the "Greats" who have gone before, the book will provide many hours of engaging reading. The history of the profession in no small measure is written in the history of this man. The collection of writings will be especially useful to students of agricultural price analysis, in that it focuses on issues of enduring interest (such as model specification, simultaneity, measurement error) with a grace and clarity that is at once refreshing and enlightening. (It's no small matter, I believe, that Fox's undergraduate degree was in English.) The arrow charts describing the structure of specific industries (such as beef, pork, chicken, and dairy) could be profitably incorporated into lecture material to explain some of the more thorny questions about endogeneity and simulation. Finally, the historical perspectives gained from reading this volume provide a catharsis of sorts in that the book deepens one's understanding of and appreciation for the antecedents of present-day disciplinary knowledge. Taken together with the quality of the editors' commentary, the volume sets a high standard for the sequel.

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Correction

An incorrect price was listed on a book reviewed in the previous issue of JAER. The book is *Market Demand for Dairy Products,* edited by S.R. Johnson, D. Peter Stonehouse, and Zuhair Hassan, and published by Iowa State University Press. The correct price is $55.95.

United States
Department of Agriculture
1301 New York Avenue, NW
Washington, DC 20005-4789